

**PETROGRAPHIC REPORT ON SEVENTY-
EIGHT ROCK SAMPLES FROM
CAMBRIAN VOLCANIC AND VOLCANO-
SEDIMENTARY SEQUENCES IN
NORTHERN AND NORTH-WESTERN
TASMANIA**

For

Zinifex Rosebery Mine

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SUMMARY

Introduction

A suite of seventy-eight rock samples from surface outcrops of Cambrian volcanic and volcano-sedimentary sequences in northern and north-western Tasmania, were submitted for petrographic preparation, description and interpretation. The sampled sequences are considered to be correlatives of the Cambrian Mount Read Volcanics of western and north-western Tasmania. A batch of 61 samples from the Castra-Nietta area were initially submitted, but these were shortly followed by a further 17 samples from the region between Sheffield and the Dial Range. The samples were identified in the number series between 378103 and 378189, but with gaps in sequence (i.e. there was no sample 378117, 378122-4, 378134, 378169-72).

Standard thin sections were prepared from each sample and all offcuts from the sections were treated with hydrofluoric acid and sodium cobaltinitrite in order to test for the presence of K-feldspar. This step proved invaluable as many of the altered volcanic and volcano-sedimentary rocks contained fine grained K-feldspar and knowledge about the amount of K-feldspar aided rock classification. Several samples contained carbonate and these were tested with dilute HCl to check for carbonate speciation. All rocks were measured for magnetic susceptibility. Many of the volcanic, epiclastic and possible intrusive rocks in the suite were moderately to strongly magnetic, which, together with the presence of relict clinopyroxene (and rare hornblende), or pseudomorphs thereof, indicate that the magmatic source(s) for the igneous rocks were of I-type.

Microscopic examination of the thin sections was made in transmitted and oblique reflected light and this allowed samples in the suite to be classified into the following major groups: clastic sedimentary, epiclastic, pyroclastic, probable extrusive (lava) and probable intrusive. In the descriptions, the term "epiclastic" denotes a clastic sedimentary rock with a dominant immature volcanic provenance; in the suite, most volcanic material is of intermediate to felsic composition. Many of the interpretations of primary rock type based on petrography vary somewhat from field descriptions, but this is to be expected, based on firmer textural and mineralogical criteria. In the main, the field descriptions are reasonably accurate and most of the interpretative differences lie in the distinction between rocks that might be pyroclastic versus sedimentary (epiclastic) and between sedimentary (epiclastic) and porphyritic coherent volcanics (e.g. lava). In several samples, it has not been possible to unequivocally assign an interpreted origin (e.g. epiclastic versus pyroclastic, or extrusive versus intrusive).

Summary descriptions of each sample are listed below:

378103 TS

Summary: Coarse grained lithic-crystal felsic tuff, with abundant tightly packed, angular lithic and mineral grains. There is no diagnostic textural evidence to indicate that the rock represents a reworked pyroclastic, i.e. a coarse epiclastic sandstone. Lithic fragments are dominated by volcanic material (mostly pumice, glassy and porphyritic grains), with a tiny population of fine grained carbonaceous sedimentary material. Individual mineral grains are dominated by volcanic-derived quartz and plagioclase, but there are a few small, altered ferromagnesian grains. The matrix is fine to medium grained and composed of altered pumiceous material. The rock has undergone strong alteration of sodic-propylitic type, with dominant replacement by albite, with patchy chlorite and a little quartz, sericite plus trace leucoxene, pyrite and sphalerite.

378104 TS

Summary: Coarse grained lithic sandstone, grading into conglomerate, with a wide variety of lithic and individual mineral grain types. Detrital grains are tightly packed and there is little matrix. Lithic grains include fine grained sedimentary/metasedimentary types (e.g. shale, carbonaceous shale, siltstone, siliceous argillite/chert, marble) and fine to medium grained mafic to intermediate igneous types (e.g. intermediate to mafic porphyritic lava, dolerite). Individual mineral grains include plagioclase, quartz, clinopyroxene, calcite and FeTi oxide. The rock has undergone only weak alteration, with relatively minor replacement by albite, chlorite, carbonate and traces of leucoxene and pyrite.

378105 TS

Summary: Coarse grained lithic sandstone, with a wide variety of lithic and individual mineral grain types. Detrital grains are tightly packed with only a little matrix. Lithic grains include fine grained sedimentary/metasedimentary types (e.g. shale, carbonaceous shale, siliceous argillite/chert, recrystallised limestone) and fine to medium grained mafic igneous types (e.g. basaltic porphyritic lava, dolerite). Individual mineral grains include plagioclase, quartz, clinopyroxene, calcite and altered ferromagnesian material. The rock has undergone only weak alteration, with relatively minor replacement by albite, chlorite, carbonate, sericite and traces of leucoxene, sphalerite, pyrrhotite, chalcopyrite and pyrite.

378106 TS

Summary: Moderately weathered, medium grained lithic-quartz sandstone. The detrital lithic grains and mineral grains are rather tightly packed and there is only minor matrix. Weak bedding laminations are locally present. The lithic detrital grains include a substantial fine grained sedimentary component (shale, siltstone, chert and quartzite grains) as well as a fine grained altered volcanic component. The rock has undergone moderate to strong alteration, with replacement of lithic and plagioclase grains and the matrix. The alteration assemblage is dominated by chlorite and sericite, with minor albite and quartz. Weathering effects have been imposed, leading to extensive goethite staining.

378107 TS

Summary: Porphyritic quartz latite or quartz micromonzonite with pervasive, strong propylitic alteration. The rock originally contained phenocrysts of plagioclase and less common ferromagnesian grains (e.g. pyroxene, hornblende), as well as a few glomeroporphyritic aggregates of plagioclase-ferromagnesian-FeTi oxide in a fine to medium grained inequigranular groundmass dominated by K-feldspar, plagioclase and quartz. Alteration has led to development of an alteration assemblage of albite, chlorite and epidote, with a little actinolite.

378108 TS

Summary: Medium grained lithic-quartz-feldspar sandstone (greywacke), with moderate to strong alteration of propylitic type. The rock has abundant detrital lithic grains (mostly fine grained sedimentary types, but with a small mafic to intermediate igneous grain population) along with detrital plagioclase, quartz and a little altered ferromagnesian material and FeTi

oxide. Alteration has led to local replacement by albite, chlorite, carbonate, sericite and hematite and has evidently occurred under rather oxidising conditions, perhaps related to very low grade metamorphism.

378109 TS

Summary: Coarse grained lithic-quartz sandstone, grading into conglomerate. Most coarse detrital clasts are composed of fine grained sedimentary material, dominated by hematite-pigmented shale, siliceous argillite and chert (some being radiolarian). There are also a few siltstone, quartzite and altered porphyritic ?mafic volcanic clasts. The rock also has a large population of smaller discrete sand-sized mineral grains, mostly quartz, but with minor plagioclase and a little muscovite. A small silty to muddy matrix component has been altered and recrystallised. The rock has sustained weak deformation effects, leading to development of a weak foliation. Alteration effects, with development of sericite, carbonate, chlorite and minor amounts of hematite and a clay phase may be due to very low grade metamorphism.

378110 TS

Summary: Altered fine to medium grained lithic-crystal tuff, with a dominance of pumiceous lithic grains and smaller populations of quartz, feldspar and altered ferromagnesian grains. The rock has been subject to strong replacement, with originally glassy pumiceous material having been totally replaced by fine grained K-feldspar and a smaller amount of quartz, albite and chlorite. The alteration assemblage also contains a little sericite and traces of leucoxene, pyrite and epidote. It is interpreted to be transitional between potassic and propylitic types, and probably a result of very low grade metamorphism.

378111 TS

Summary: Coarse grained lithic-feldspathic sandstone, with a mixed provenance of sedimentary and volcanic material. Lithic grains are dominated by massive to weakly foliated shale-siltstone (locally carbonaceous) and intermediate to mafic volcanic material, but with minor quartz-rich metasedimentary material (e.g. quartzite, metachert) and felsic pumiceous material. There are abundant detrital plagioclase grains, with minor quartz and altered ferromagnesian material. There is a minor shale-siltstone matrix component. The rock has undergone moderate alteration, perhaps as the result of very low grade metamorphism, with the partial replacement of lithic and mineral grains, and the matrix, by chlorite, carbonate, sericite and albite. In places, a weak foliation is evident, defined by preferred orientation of chloritised volcanic grains and by incipient carbonaceous stylolites.

378112 TS

Summary: Coarse grained lithic-feldspar-quartz sandstone, with abundant lithic clasts dominated by altered volcanic material, but with a smaller population of fine grained sedimentary material. There are also abundant individual mineral grains, dominated by plagioclase and quartz, and a small matrix component. The rock has under pervasive, moderate to strong propylitic alteration, perhaps caused by very low grade metamorphism, with replacement by chlorite, carbonate, albite, sericite, a little leucoxene/rutile and trace pyrite.

378113 TS

Summary: Medium to coarse grained lithic sandstone, with minor detrital quartz and plagioclase grains. The lithic grains are dominated by fine grained sedimentary material (shale, siltstone, siliceous argillite, chert/jasper, quartzite) and intermediate to mafic igneous material (?andesite/basalt, dolerite). There is only a minor matrix component. The rock has undergone strong propylitic alteration and replacement by chlorite, with subordinate albite, quartz and minor sericite. There are also a couple of thin quartz veins. A little pyrite might have formed as part of the alteration assemblage but was later replaced by goethite as a result of weathering.

378114 TS

Summary: Retrogressively altered fine to medium grained mafic igneous rock, perhaps originally a quartz dolerite. Although the rock contains relict clinopyroxene, it is possible that this phase represents a metamorphic product replacing earlier igneous clinopyroxene. The original igneous rock contained considerable plagioclase, with interstitial K-feldspar and quartz and a little disseminated FeTi oxide. The rock could have been metamorphosed, leading to recrystallisation of clinopyroxene, but was then retrogressively altered, with replacement by abundant chlorite, albite, epidote and minor carbonate, pyrite and leucoxene. The rock has been cut by a few thin sheared zones, along which development of chlorite, epidote and carbonate is prevalent.

378115 TS

Summary: Coarse grained lithic-crystal felsic tuff, composed mainly of pumiceous and flow-foliated and porphyritic felsic volcanic fragments and individual volcanic quartz grains (former phenocrysts) set in a fine to medium grained pumiceous matrix. There is no textural evidence for sedimentary re-working of the pyroclastic rock. There has been strong and pervasive alteration of transitional phyllic-propylitic type that has caused replacement of all volcanic lithic material and uncommon feldspar, ferromagnesian and FeTi oxide grains. The alteration assemblage is dominated by fine grained sericite and quartz, with minor chlorite and a little leucoxene.

378116 TS

Summary: Medium to coarse grained lithic tuff, dominated by former pumiceous fragments. It is possible that the rock represents an altered felsic to intermediate volcanic composition. The rock may have also contained a few feldspar grains and small grains of FeTi oxide. Very strong phyllic alteration, perhaps caused by hydrothermal processes, has overprinted the original pyroclastic material, partially destroying relict texture and causing total replacement by fine grained sericite and quartz, with scattered porphyroblastic grains of carbonate, a little leucoxene and hematite, and a trace of pyrite.

378118 TS

Summary: Medium grained quartz-lithic-feldspathic sandstone, with abundant angular to sub-rounded detrital grains of quartz and lithic, with minor plagioclase and a little muscovite, traces of biotite, K-feldspar, tourmaline, zircon, leucoxene and chromite. Most lithic grains are composed of fine grained shaly material, with local grains being pigmented by carbonaceous material. Other lithic grains are cherty or quartzitic and rare grains contain fuchsite, which, along with the trace grains of chromite, indicate a minor ultramafic source for detritus. The rock has developed substantial amounts of carbonate, along with minor sericite, in the matrix, perhaps due to very low grade metamorphism.

378119 TS

Summary: Altered porphyritic, slightly amygdaloidal dacite, originally containing scattered phenocrysts of plagioclase and ferromagnesian material (mostly pyroxene), plus microphenocrysts of FeTi oxide and quartz in a fine grained feldspathic groundmass. The rock has undergone low grade alteration of propylitic type that has caused development of a replacement assemblage of albite, with subordinate sericite and chlorite, with minor carbonate, quartz and leucoxene/rutile. Amygdules are filled by one or more of quartz, carbonate, sericite and chlorite.

378120 TS

Summary: Altered medium to coarse grained lithic-feldspathic-quartz sandstone, exhibiting a strong volcanic provenance, with intermediate to felsic volcanic detritus. Lithic grains are dominated by altered porphyritic, fine grained (aphanitic) intermediate volcanic material and feldspar grains are dominated by altered plagioclase. A subordinate amount of fine grained

partly recrystallised matrix material is present, with dominant albite and minor K-feldspar, quartz and chlorite. The rock has undergone low grade alteration of propylitic type, probably as a result of incipient metamorphism. Albite and chlorite are the main alteration minerals, with a little sericite. A trace of pyrite may have developed as part of the alteration assemblage, but most has subsequently been replaced by goethite as a result of supergene oxidation.

378121 TS

Summary: Altered fine grained porphyritic felsic volcanic rock, possibly representing a former lava. The rock contained scattered feldspar phenocrysts and possible microphenocrysts of ferromagnesian material and FeTi oxide in a fine grained quartzofeldspathic groundmass. There has been very strong pervasive alteration, likely to be caused by hydrothermal action. This has resulted in the replacement of the igneous rock by a phyllic assemblage of quartz and sericite-illite, with traces of rutile and hematite.

378125 TS

Summary: Altered mildly porphyritic and amygdaloidal fine grained felsic igneous rock, probably of dacitic to rhyolitic composition and maybe representing a lava. The original rock contained scattered phenocrysts of plagioclase and rare ferromagnesian material in a fine grained quartzofeldspathic groundmass containing scattered vesicles. The rock has undergone strong pervasive alteration of transitional phyllic-propylitic type, with replacement by albite and subordinate quartz and sericite, with a little K-feldspar. Vesicles were filled by quartz and sericite, forming amygdules.

378126 TS

Summary: Altered porphyritic quartz latite or rhyodacite, possibly representing a shallow intrusive or lava. The rock contained scattered phenocrysts of plagioclase, hornblende and possibly pyroxene in a fine grained holocrystalline groundmass dominated by K-feldspar, plagioclase and quartz. The rock has undergone pervasive strong alteration, with replacement of plagioclase by albite and development of biotite, chlorite and sericite/muscovite, mainly from replacement of the ferromagnesian phases. In the groundmass, there has been development of a few metasomatic patches of quartz, biotite and muscovite.

378127 TS

Summary: Sparsely porphyritic and weakly flow foliated intermediate to felsic igneous rock, perhaps representing a lava. There are pseudomorphs after a few phenocrysts of feldspar and ferromagnesian phases, plus a few altered volcanic fragments, hosted in a fine grained altered quartzofeldspathic groundmass. The rock has undergone strong oxidative alteration of phyllic type, with replacement by fine grained quartz, sericite and hematite.

378128 TS

Summary: Medium to coarse grained lithic-crystal tuff of intermediate to felsic composition, but with some possibility that the rock has been reworked to form an epiclastic sandstone. There is abundant volcanic lithic material, dominated by pumiceous grains, as well as abundant altered plagioclase and minor quartz and altered ferromagnesian grains. The rock has been strongly and pervasively altered to an assemblage that is viewed as being transitional between potassic and propylitic. There has been considerable replacement by albite, K-feldspar, chlorite, carbonate and minor quartz and sericite. The altered rock contains a trace of pyrite and has been cut by rare thin carbonate veins.

378129 TS

Summary: Altered porphyritic quartz latite, perhaps representing a former shallow intrusive or lava. The original rock contained scattered phenocrysts of plagioclase and less common phenocrysts of a ferromagnesian phase (maybe pyroxene) and microphenocrysts of FeTi oxide and quartz. There are also one or two glomeroporphyritic aggregates of plagioclase-

ferromagnesian phase-FeTi oxide. Phenocrystal phases occur in a fine grained, holocrystalline groundmass dominated by K-feldspar and plagioclase, with minor quartz and ferromagnesian material. The rock has under moderate to strong and pervasive propylitic alteration, with partial replacement of the igneous minerals by albite, chlorite and a little sericite, leucoxene and titanite.

378130 TS

Summary: Very strongly altered porphyritic felsic volcanic rock, maybe representing a lava. The original rock may have had scattered feldspar and a few ferromagnesian phenocrysts, set in a fine grained quartzofeldspathic groundmass. The rock has undergone complete replacement by a phyllic assemblage, maybe as a result of hydrothermal alteration. There has been recrystallisation to an assemblage of quartz and subordinate sericite, with traces of leucoxene. Minor clay (possibly kaolinite) occurs at several altered feldspar sites and could be partly the result of later imposed weathering. The latter process has given rise to local goethite staining.

378131 TS

Summary: Altered porphyritic felsic volcanic rock, maybe representing a lava. The original rock contained scattered large quartz phenocrysts along with less common feldspar and ferromagnesian phenocrysts in a fine grained quartzofeldspathic groundmass. There has been very strong alteration imposed, probably due to hydrothermal processes, leading to replacement of groundmass, feldspar and ferromagnesian materials by quartz and sericite, with traces of leucoxene/rutile and tourmaline. The altered rock has been cut by a few veins, with early thin quartz veins cut by later sub-planar tourmaline-pyrite-quartz veins.

378132 TS

Summary: Porphyritic and weakly amygdaloidal quartz latite, perhaps emplaced originally as a lava. It contained scattered phenocrysts of plagioclase and a ferromagnesian phase, plus a few microphenocrysts of FeTi oxide and quartz in a fine grained quartzofeldspathic groundmass rich in K-feldspar. The rock has been altered to a propylitic assemblage, with partial replacement of igneous minerals by albite, chlorite, carbonate, sericite and trace leucoxene. Amygdules and uncommon veinlike aggregates contain quartz, carbonate and chlorite. There are two types of carbonate as part of the alteration assemblage; one is brownish and Fe-bearing, the other may be more dolomitic.

378133 TS

Summary: Strongly altered porphyritic felsic volcanic rock, probably representing a former amygdaloidal lava. The rock contains scattered variably altered plagioclase phenocrysts and a few quartz microphenocrysts in a fine grained altered and recrystallised quartzofeldspathic groundmass. Alteration may have been due to hydrothermal processes and has caused the patchy replacement and veining of the groundmass by fine to medium grained quartz and a minor sericite. Amygdular patches have been filled by quartz, with the remainder of the groundmass having been replaced by fine grained K-feldspar, plus minor albite, quartz and sericite. Plagioclase phenocrysts have been variably replaced by albite and sericite.

378135 TS

Summary: Strongly altered porphyritic, fine grained felsic igneous rock, maybe representing a former lava. The original rock contained scattered feldspar phenocrysts, and possibly a few quartz phenocrysts and ferromagnesian microphenocrysts in a fine grained quartzofeldspathic groundmass. The rock has undergone strong phyllic alteration, maybe as a result of hydrothermal processes, with total recrystallisation of the groundmass to fine to medium grained inequigranular quartz and subordinate amounts of sericite.

378136 TS

Summary: Porphyritic, fine grained felsic to intermediate igneous rock, maybe representing a former lava or shallow intrusive, with very strong alteration of phyllic type. The original rock contained scattered feldspar phenocrysts, and a few ferromagnesian microphenocrysts in a fine grained quartzofeldspathic groundmass. Alteration may be due to hydrothermal processes and has resulted in almost complete replacement of igneous materials by fine to medium grained quartz, sericite and traces of leucoxene and hematite. The altered groundmass has characteristic inequigranular quartz, with minor sericite, as well as a few coarser alteration aggregates of quartz and sericite.

378137 TS

Summary: Coarse grained lithic-crystal felsic tuff or derived epiclastic sandstone (grading into conglomerate). Relict textures are not diagnostic to distinguish due to alteration and recrystallisation. The rock has abundant lithic clasts that include volcanic material (pumice and porphyritic grains) as well as fine grained low grade metasedimentary material (mica schist, etc.). There are also individual mineral grains dominated by former volcanic-sources quartz and plagioclase. The matrix interstitial to lithic and mineral grains is composed largely of former fine pumiceous material. The rock has undergone strong alteration of propylitic type, with replacement by albite and lesser amounts of quartz, K-feldspar, sericite and chlorite. A few thin veins cut the altered rock and contain quartz \pm albite, chlorite. The rock has been weakly deformed, with slight development of a foliation defined by preferred orientation of alteration-derived sericite.

378138 TS

Summary: Well laminated shale-siltstone, with good preservation of detrital grains and sedimentary bedding. Laminations are planar and sharp to gradational, with detrital grains dominated by plagioclase, K-feldspar, quartz and fine grained lithics. Matrix to the coarser laminae, as well as the finer, shaly laminae, is dominated by chlorite, with patchy development of carbonate. Shaly laminae may contain a little carbonaceous material and traces of pyrite. Alteration in the rock may be due to very low grade metamorphism and is dominated by an assemblage of albite, chlorite and carbonate, with a little sericite.

378139 TS

Summary: Coarse grained lithic-crystal felsic tuff, dominated by pumiceous fragments and a minor pumiceous matrix component. There is a minor population of other lithic fragments including foliated carbonaceous shale/siltstone and quartzite, as well as individual mineral grains dominated by volcanic quartz and plagioclase grains. There is little evidence for the volcanic components to have been reworked to form an epiclastic sandstone. The rock has undergone strong alteration that is interpreted to be transitional between propylitic and potassic. There has been replacement of former igneous components by albite, sericite, K-feldspar, quartz, chlorite, carbonate and traces of leucoxene and pyrite.

378140 TS

Summary: Strongly altered medium to coarse grained lithic-crystal tuff, probably of intermediate to felsic composition. The rock contains abundant fine grained volcanic lithic fragments (mostly porphyritic, but some pumiceous), plus scattered altered plagioclase grains and rare quartz grains in a fine to medium grained pumiceous matrix. Pervasive strong alteration of transitional propylitic-potassic type has been imposed, with replacement by albite, K-feldspar, chlorite, carbonate, sericite and quartz. In places, porphyroblasts of carbonate have grown and there is a trace of disseminated pyrite as part of the alteration assemblage. The carbonate is Fe-bearing and slight weathering effects have led to partial replacement of carbonate (and pyrite) by goethite.

378141 TS

Summary: Massive, medium to coarse grained feldspathic-lithic sandstone, evidently from an intermediate volcanic (e.g. andesitic) provenance. The rock contains abundant altered angular detrital grains of plagioclase and volcanic lithics, with minor altered ferromagnesian and a

little FeTi oxide and quartz. There has been strong pervasive alteration, probably caused by very low grade metamorphism, with replacement by an assemblage dominated by albite and chlorite, with a little sericite, carbonate and leucoxene.

378142 TS

Summary: Porphyritic quartz micromonzonite, probably representing a shallow intrusive rock. It contained scattered phenocrysts of plagioclase and ferromagnesian material in a fine to medium grained groundmass of K-feldspar, plagioclase, quartz, ferromagnesian material and FeTi oxide. There are a few glomeroporphyritic aggregates of plagioclase, ferromagnesian material, FeTi oxide and trace apatite. The rock has undergone rather strong propylitic alteration, with replacement by an assemblage of albite, chlorite, actinolite and sericite. Weathering effects have led to further degradation to nontronite and goethite.

378143 TS

Summary: Porphyritic microgranodiorite with moderate to strong propylitic alteration. The rock contains scattered plagioclase phenocrysts and less common altered ferromagnesian phenocrysts and a few small quartz phenocrysts in a fine to medium grained, holocrystalline, inequigranular groundmass of plagioclase, K-feldspar, quartz, altered ferromagnesian material and disseminated FeTi oxide. There is no textural evidence for the rock to represent an epiclastic sandstone. There has been pervasive alteration, with partial replacement of plagioclase by albite, chlorite and sericite, and ferromagnesian by chlorite and sericite. A few scattered quartz aggregates in the groundmass may also be due to alteration. Weathering effects have caused local goethite staining.

378144 TS

Summary: Altered porphyritic rhyodacite or quartz latite, originally containing phenocrysts and small glomeroporphyritic aggregates of plagioclase, ferromagnesian minerals (most likely pyroxene and biotite) and FeTi oxide in a fine to medium grained, holocrystalline groundmass dominated by K-feldspar and quartz. The rock has undergone very low grade metamorphism (and/or propylitic alteration) to yield an assemblage dominated by albite and chlorite, with a little sericite and traces of hematite, titanite, epidote and leucoxene.

378145 TS

Summary: Medium to coarse grained lithic-crystal felsic tuff, with strong and pervasive alteration of transitional phyllic-propylitic type. The rock has abundant relict volcanic quartz grains as well as altered lithic fragments, most of which were aphanitic/glassy and some porphyritic or pumiceous. All former lithic grains as well as uncommon feldspar, biotite and FeTi oxide grains have been replaced by fine grained sericite and chlorite, with a little quartz and leucoxene.

378146 TS

Summary: Altered medium grained feldspathic-lithic (-quartz) sandstone, with a provenance from an intermediate to felsic volcanic source. The rock contains detrital grains of altered plagioclase, altered ferromagnesian material and minor lithics and quartz. Lithic grains include altered volcanic material. The rock has undergone very low grade metamorphism, leading to partial replacement of the primary components and development of an assemblage of albite, chlorite and sericite, with a trace of leucoxene. Slight supergene oxidation effects have led to local formation of goethite.

378147 TS

Summary: Altered coarse grained intermediate volcanic tuff or epiclastic sandstone, probably of original andesitic to latitic composition. The rock contains tightly packed lithic fragments (porphyritic, aphanitic and locally pumiceous material) and mineral grains that include plagioclase (dominant), clinopyroxene and traces of brown hornblende, FeTi oxide and

apatite. There has been strong alteration of transitional propylitic-potassic type, probably as a result of very low grade metamorphism, with considerable replacement of original igneous detritus by albite, K-feldspar and chlorite, with lesser amounts of carbonate and epidote, a little sericite and quartz and traces of hematite, pyrite, leucoxene and pumpellyite.

378148 TS

Summary: Altered, moderately porphyritic felsic volcanic rock, probably representing a lava of dacitic composition. The original rock contained phenocrysts of plagioclase, plus a few of biotite, along with microphenocrysts of FeTi oxide and possible pyroxene in a fine grained (aphanitic/glassy) quartzofeldspathic groundmass. There is weak flow alignment of phenocrysts and of quartz-rich alteration patches in the groundmass. Pervasive strong alteration has led to replacement of the groundmass by K-feldspar, with minor quartz, sericite and hematite. Plagioclase has been replaced by variable amounts of quartz, K-feldspar, sericite and albite, with biotite being replaced by sericite \pm hematite \pm leucoxene, pyroxene by quartz \pm hematite, and FeTi oxide by hematite. The alteration may be due to low grade metamorphic effects and is of potassic-phyllitic type.

378149 TS

Summary: Altered porphyritic quartz-biotite-pyroxene latite, perhaps representing a former lava. The rock contained scattered phenocrysts of plagioclase and biotite, with a few glomeroporphyritic aggregates of plagioclase-pyroxene-biotite-FeTi oxide-apatite and a few microphenocrysts of FeTi oxide in a fine grained (perhaps aphanitic) groundmass that was rich in K-feldspar, plus minor quartz, plagioclase and ferromagnesian material. There has been moderate to strong pervasive alteration of propylitic type imposed, with partial replacement of igneous minerals by albite, sericite, chlorite, carbonate and trace leucoxene. A few irregular veins cut the altered rock; they range from quartz-rich, with K-feldspar selvages to carbonate-rich.

378150 TS

Summary: Medium grained lithic-feldspathic-quartz sandstone, with a mixed felsic to intermediate volcanic and sedimentary provenance. Lithic grains include volcanic material as well as fine grained siliceous and sericitic sedimentary material. The rock has undergone pervasive strong alteration under oxidising conditions to develop an assemblage of albite, quartz, carbonate (e.g. dolomite), sericite and hematite.

378151 TS

Summary: Medium to coarse grained lithic-crystal tuff, probably of intermediate to felsic composition. The rock has abundant angular volcanic lithic fragments as well as a population of altered plagioclase grains, a small amount of altered ferromagnesian and FeTi oxide material, all enclosed in a fine grained, altered and recrystallised volcanoclastic matrix, probably originally composed of fine ash. Volcanic fragments are fine grained, commonly sparsely porphyritic, with some having perlitic cracking texture and pumiceous texture. Many volcanic fragments contain fine grained K-feldspar, but much of the rock (matrix, fragments and plagioclase grains) has been replaced by fine grained (and locally medium grained) albite, along with minor chlorite, a little quartz, sericite and traces of epidote, leucoxene and hematite.

378152 TS

Summary: Coarse grained lithic-crystal tuff, grading to volcanic breccia. The rock is probably of felsic composition and contains abundant lithic fragments that include former glassy, pumiceous and porphyritic material. There is also a smaller population of mineral grains (mainly plagioclase, with minor quartz and altered ferromagnesian and FeTi oxide grains), all hosted in an altered and finely recrystallised matrix, perhaps originally composed of fine ashy pumiceous material. The rock has undergone feldspathic alteration, with replacement of many volcanic fragments by fine grained K-feldspar, or by albite \pm quartz \pm chlorite \pm sericite. Matrix material has been finely recrystallised into dominant albite \pm quartz \pm sericite.

378153 TS

Summary: Medium grained lithic-crystal tuff or epiclastic sandstone, with a mostly felsic volcanic provenance (but with a small contribution from a siliceous metamorphic source). Lithic grains are dominated by former pumiceous material, but there is a small population of fine grained quartz-rich and quartz-muscovite grains. Mineral grains are dominated by altered plagioclase and quartz, with a few muscovite flakes. Pervasive strong alteration has been imposed, with total replacement of pumiceous material by fine grained K-feldspar, plus subordinate chlorite, minor carbonate and quartz. Plagioclase has been albitised and also flecked by sericite. Alteration is considered to be of transitional potassic-propylitic type.

378154 TS

Summary: Moderately altered, porphyritic and slightly flow foliated felsic volcanic rock, probably representing a lava of rhyodacite composition. The rock contains scattered partly altered phenocrysts of plagioclase and pseudomorphs after a few microphenocrysts of ferromagnesian material and FeTi oxide, set in a partly recrystallised, fine grained groundmass dominated by K-feldspar and plagioclase. The rock has undergone moderate alteration to a propylitic assemblage of albite, with minor chlorite, carbonate and sericite, and the emplacement of several elongate veinlike aggregates (perhaps co-planar with flow foliation) of quartz \pm chlorite.

378155 TS

Summary: Altered porphyritic and amygdaloidal rhyodacite or quartz latite. The original rock contained scattered phenocrysts of plagioclase and minor ferromagnesian material, along with amygdules, set in a fine grained groundmass rich in K-feldspar, quartz and plagioclase. The rock has undergone strong pervasive propylitic alteration, with development of albite, sericite, carbonate (dolomite) and a little chlorite and rutile. Amygdules are filled by quartz, with minor carbonate, sericite and chlorite. A few thin sub-planar quartz-rich veins cut the altered rock.

378156 TS

Summary: Altered porphyritic and possibly spheroidal felsic volcanic rock, probably representing a former lava. The rock contained scattered tabular plagioclase phenocrysts and uncommon ferromagnesian microphenocrysts in an originally fine grained/glassy quartzofeldspathic groundmass. Alteration and recrystallisation of the groundmass has led to the formation of scattered irregular to ovoid and spheroidal aggregates of quartz and K-feldspar. Elsewhere, the rock has been replaced by albite, K-feldspar, chlorite and minor sericite, with development of a few thin veins that are rich in sericite or in quartz.

378157 TS

Summary: Altered porphyritic quartz latite maybe representing a shallow intrusive or less likely, a lava. The original rock contained scattered phenocrysts of plagioclase and a few microphenocrysts of ferromagnesian material and quartz in a holocrystalline, fine to medium grained groundmass of plagioclase, K-feldspar, minor altered ferromagnesian material, quartz and FeTi oxide. The rock contains a few glomeroporphyritic aggregates (?micro-enclaves) of plagioclase-altered ferromagnesian material-FeTi oxide and quartz. There has been pervasive propylitic alteration, probably the result of very low grade metamorphism, with partial replacement by albite, chlorite, sericite and carbonate.

378158 TS

Summary: Porphyritic quartz micromonzonite, with scattered small plagioclase phenocrysts set in a fine to medium grained groundmass of plagioclase, K-feldspar, altered ferromagnesian material, minor quartz and FeTi oxide. Pervasive strong propylitic alteration has been imposed, with partial replacement by albite and chlorite, plus minor carbonate and hematite.

378159 TS

Summary: Altered porphyritic quartz monzonite. The original igneous rock contained abundant tabular plagioclase phenocrysts, with interstitial medium grained K-feldspar, ferromagnesian material and minor quartz, plagioclase and FeTi oxide (titanomagnetite). There has been moderate to strong imposed alteration of propylitic type. This has led to replacement of some of the primary minerals by albite and chlorite, with minor carbonate, sericite and epidote, plus traces of titanite and leucoxene.

378160 TS

Summary: Porphyritic and possibly amygdaloidal quartz latite, with moderate to strong propylitic alteration. The original igneous rock contained scattered phenocrysts of plagioclase and probably pyroxene in a fine grained, holocrystalline groundmass dominated by K-feldspar, but with minor plagioclase, quartz and ferromagnesian material. There are a few glomeroporphyritic aggregates of former plagioclase, pyroxene, FeTi oxide and apatite and in the groundmass, several aggregates that might represent amygdules. There has been total replacement of igneous plagioclase, pyroxene and FeTi oxide by an assemblage of albite, chlorite and carbonate, with a little sericite, leucoxene, hematite and pyrite. Amygdules are filled by carbonate, in places with accompanying quartz and a little sericite.

378161 TS

Summary: Altered porphyritic quartz micromonzonite, with scattered plagioclase phenocrysts. The rock contains abundant fine to medium grained K-feldspar and quartz, with subordinate amounts of altered ferromagnesian material (originally included biotite). Interstitial K-feldspar and quartz commonly display micrographic intergrowths. The rock has undergone low grade propylitic alteration with partial replacement by albite, chlorite and sericite. Slight weathering effects have led to the formation of goethite staining and aggregates. There is no textural evidence for the rock to be a volcanoclastic sandstone.

378162 TS

Summary: Altered porphyritic quartz latite, perhaps representing a shallow intrusive. The original rock contained phenocrysts of plagioclase, ferromagnesian material (probably pyroxene) and microphenocrysts of FeTi oxide. There are a few glomeroporphyritic aggregates of the same minerals. The groundmass is fine to medium grained and dominated by plagioclase, K-feldspar and quartz. Strong pervasive alteration of propylitic type has been imposed, maybe as a result of very low grade metamorphism, with replacement of igneous minerals by albite, chlorite plus a little sericite, epidote and leucoxene.

378163 TS

Summary: Medium to coarse grained volcanoclastic sandstone with intermediate to felsic volcanic provenance. The rock contains abundant altered lithic detrital grains (fine grained and locally porphyritic and flow-foliated intermediate volcanic material), plus altered plagioclase grains, quartz and a little detrital muscovite. Detrital components occur in a fine grained quartzofeldspathic matrix. The rock has undergone pervasive propylitic alteration to develop an assemblage of dominant albite, with subordinate quartz and chlorite, minor carbonate, a little sericite and trace rutile and pyrite.

378164 TS

Summary: Medium grained quartz-lithic sandstone with a mixed provenance dominated by grains of siliceous metamorphic material, possible felsic plutonic, fine grained sedimentary, volcanic and trace ultramafic material. The rock has undergone moderate alteration, with development of chlorite and carbonate, mainly from replacement of volcanic grains, matrix and development of cement. A trace of disseminated pyrite occurs as part of the alteration assemblage.

378165 TS

Summary: Medium grained quartz-lithic sandstone containing detrital grains of quartz, subordinate amount of lithic material (quartzite and quartz-muscovite schist), scattered grains of muscovite, a little altered biotite, K-feldspar and carbonate and traces of tourmaline, rutile and chromite. The minor amount of matrix component has been recrystallised as a result of low grade metamorphism and consists of quartz, chlorite, carbonate and a little sericite. Rare pyrite grains might have also formed as a result of matrix alteration. The rock is likely to have had a provenance from a mature silicic metamorphic source, rather than from a volcanic source.

378166 TS

Summary: Well laminated carbonaceous shale-siltstone. The rock contains detrital grains of quartz and muscovite, with minor lithics and K-feldspar in a fine grained matrix of chlorite, with minor sericite, quartz and carbonaceous material. The latter might represent former organic material, subsequently matured into a graphite-like substance. It is locally accompanied by traces of fine grained pyrite. The rock may have undergone very low grade metamorphism and the mica flakes display a weak preferred orientation.

378167 TS

Summary: Strongly altered medium to coarse grained lithic-crystal felsic tuff. The rock contains tightly packed lithic grains (mostly altered pumice) and altered plagioclase grains, with minor quartz, in a finer grained pumiceous matrix. There has been replacement of the igneous material by albite, quartz, chlorite, K-feldspar, sericite and traces of leucoxene and pyrite, with the alteration assemblage being of propylitic type. There is no textural evidence for the rock to represent reworked volcanoclastic material (i.e. being an epiclastic sandstone).

378168 TS

Summary: Very fine grained altered felsic vitric ash or derived epiclastic siltstone. The rock is massive and un-laminated and dominated by very finely recrystallised matrix material in which there are scattered small detrital grains of quartz and altered volcanic material, including possible glass shard material. The matrix may also have been dominated by ultrafine vitric ash. There has been complete alteration and recrystallisation of the rock except for small relict quartz grains, with replacement by quartz, K-feldspar, sericite/illite and trace leucoxene. The matrix contains scattered diffuse aggregates containing a slightly higher content of sericite/illite.

378173 TS

Summary: Coarse grained felsic pyroclastic rock, probably representing a lithic-dominated type, with a small crystal component. There is no textural evidence for the components of the rock to have been substantially reworked so as to form an epiclastic sandstone. The dominant lithic fragments are altered pumiceous material and the small amount of matrix is also pumiceous, with altered glass shard fragments. Individual mineral grains are represented by a few relict volcanic quartz and altered plagioclase and ferromagnesian grains. The rock has undergone strong, pervasive alteration to an assemblage dominated by albite, quartz and sericite, with minor chlorite and carbonate, plus traces of leucoxene and pyrite. The assemblage is of propylitic type and may have formed by very low grade metamorphism (e.g. attending the formation of a weak foliation) and/or due to fluid interaction.

378174 TS

Summary: Altered porphyritic quartz micromonzodiorite, with moderately well preserved texture showing abundant plagioclase phenocrysts, a few quartz phenocrysts and glomeroporphyritic aggregates (originally with plagioclase \pm ferromagnesian material \pm quartz \pm FeTi oxide) in a fine to medium grained groundmass of plagioclase, altered ferromagnesian material, interstitial K-feldspar and quartz, and disseminated FeTi oxide. There is no textural evidence to indicate that the rock represents a clastic sedimentary type, e.g. epiclastic sandstone. There has been pervasive strong alteration of propylitic type imposed, with replacement of some of the igneous phases by albite, plus subordinate chlorite

and minor sericite, carbonate and hematite. Later weathering effects have caused the development of scattered goethite aggregates.

378175 TS

Summary: Porphyritic and locally amygdaloidal clinopyroxene latite, with scattered relict clinopyroxene phenocrysts and pseudomorphs after small plagioclase phenocrysts. The fine grained groundmass was rich in plagioclase, K-feldspar and ferromagnesian material and contained a few amygdules. The rock has been strongly and pervasively altered to a propylitic assemblage, probably due to very low grade metamorphism, with replacement of the rock (except for relict clinopyroxene and FeTi oxide) and filling of amygdules by an assemblage of albite, quartz, chlorite, pumpellyite and a little epidote. The rock has been locally brecciated and network veined by quartz, with minor chlorite, epidote and carbonate.

378176 TS

Summary: Very coarse grained intermediate volcanic fragmental rock, e.g. agglomerate, with rather tightly packed porphyritic and amygdaloidal fragments. The original rock may have been of andesite or latite composition and had scattered plagioclase and possible ferromagnesian phenocrysts in a fine grained groundmass. There has been strong and pervasive alteration of propylitic type imposed, probably as a result of very low grade metamorphism. The original igneous minerals have been largely replaced by albite, epidote and chlorite, with minor K-feldspar, pumpellyite and quartz.

378177 TS

Summary: Medium grained, inequigranular texture quartz monzonite, probably representing an intrusive. The rock contained an original igneous assemblage of plagioclase, biotite, pyroxene and/or hornblende, interstitial K-feldspar and quartz, and disseminated FeTi oxide (titanomagnetite). Moderate to strong and pervasive alteration of propylitic type has been imposed, with some replacement of igneous minerals by albite, actinolite, chlorite and epidote. There are also a couple of veins containing epidote, albite and minor quartz.

378178 TS

Summary: Porphyritic clinopyroxene latite, with moderate to strong propylitic alteration and a few amygdules. The rock contains some fresh relict phenocrysts of clinopyroxene, although some are altered to chlorite. Former plagioclase phenocrysts are totally altered. The groundmass of the rock is fine grained and holocrystalline and dominated by K-feldspar and small plagioclase laths. The alteration assemblage is probably due to very low grade metamorphism and comprises albite, chlorite and a little carbonate and sericite; amygdules are largely filled by quartz, with a little carbonate and chlorite. The rock has been cut by one or two thin veins containing quartz, carbonate and chlorite.

378179 TS

Summary: Porphyritic rhyodacite, perhaps representing a lava or shallow intrusive. The rock contains relict phenocrysts of quartz as well as altered phenocrysts of plagioclase in a fine grained groundmass dominated by K-feldspar, with minor quartz, plagioclase and altered ferromagnesian material. The rock has undergone moderate to strong propylitic alteration, with development of albite, plus minor chlorite, carbonate and sericite. A few thin extensional veins of quartz (-carbonate-chlorite) cut the altered rock.

378180 TS

Summary: Medium grained, inequigranular texture quartz monzonite, probably representing an intrusive. The rock contained an original igneous assemblage of K-feldspar, plagioclase, biotite, pyroxene and/or hornblende, interstitial quartz, disseminated FeTi oxide (titanomagnetite) and traces of titanite and apatite. Moderate to strong and pervasive alteration of propylitic type has been imposed, most likely as a result of very low grade

metamorphism. The alteration assemblage is composed of albite, actinolite, chlorite and pumpellyite.

378181 TS

Summary: Porphyritic quartz-clinopyroxene latite, with moderate to strong propylitic alteration. The rock originally contained phenocrysts of plagioclase, clinopyroxene and quartz, with microphenocrysts of FeTi oxide in a fine grained (almost aphanitic) groundmass rich in K-feldspar. The groundmass also hosts a few glomeroporphyritic aggregates of plagioclase-clinopyroxene-FeTi oxide as well as rare small angular xenoliths of siltstone. Pervasive alteration has seen replacement of plagioclase by albite, sericite, epidote and chlorite, variably replacement of clinopyroxene by chlorite \pm epidote and FeTi oxide by hematite and leucoxene. In the groundmass there has been development of replacement patches of epidote \pm chlorite, as well as a trace of pyrite.

378182 TS

Summary: Altered and slightly weathered porphyritic quartz monzodiorite. There is no textural evidence for this rock to represent clastic sedimentary material (e.g. sandstone). The original igneous rock contained a few large plagioclase phenocrysts, intergrown with smaller plagioclase grains, ferromagnesian material (mostly pyroxene), late magmatic interstitial quartz and minor K-feldspar, disseminated FeTi oxide and a trace of apatite. The rock may represent a type of shallow intrusive. It has undergone strong alteration of propylitic type, with extensive replacement of igneous minerals by albite, sericite, chlorite and minor leucoxene. Weathering effects have caused degradation of chlorite to nontronite and formation of goethite staining and small aggregates, some of which could be pseudomorphous after former alteration-derived pyrite.

378183 TS

Summary: Altered and slightly weathered medium grained porphyritic microgranodiorite. The original igneous rock contained a few phenocrysts of plagioclase and ferromagnesian material intergrown with medium grained plagioclase, ferromagnesian material, FeTi oxide, and interstitial quartz and K-feldspar. Relict shapes suggest that the ferromagnesian included biotite and pyroxene. There has been strong pervasive alteration imposed, resulting in replacement of plagioclase by albite, epidote, chlorite and sericite, biotite by chlorite and pyroxene by actinolite. The alteration is consistent with propylitic type and was subsequently weakly overprinted by the effects of weathering, leading to goethite staining and minor degradation of chlorite to nontronite.

378184 TS

Summary: Medium to coarse grained lithic-feldspar-clinopyroxene sandstone, representing a proximal epiclastic, with an immature, intermediate volcanic source, probably of porphyritic clinopyroxene latite composition. Lithic grains are dominated by fine grained volcanics, some of which are porphyritic and others pumiceous. Individual detrital mineral grains are dominated by plagioclase, although there are scattered relict clinopyroxene grains and a minor population of FeTi oxide grains. A small matrix component includes finer volcanic detritus, including altered glass shards. The rock has undergone moderate to strong propylitic alteration, perhaps as a result of very low grade metamorphism, with partial replacement of the former igneous components by albite, chlorite and a little sericite and hematite. Slight weathering effects have led to some degradation of chlorite to nontronite and formation of goethite staining.

378185 TS

Summary: Porphyritic and amygdaloidal rhyodacite or quartz latite, with moderate to strong alteration. The rock originally contained a few phenocrysts of plagioclase and microphenocrysts of a ferromagnesian phase, set in a fine grained, holocrystalline groundmass that was dominated by K-feldspar, with subordinate quartz and plagioclase and minor ferromagnesian material. The rock has been affected by propylitic alteration, probably

as a result of very low grade metamorphism. There has been replacement by an assemblage of albite and chlorite, with a little sericite and traces of pumpellyite and leucoxene-rutile. Amygdules are partly to complete filled by quartz and chlorite, with a little sericite in places.

378186 TS

Summary: Altered porphyritic and locally brecciated rhyodacite, originally containing scattered phenocrysts of plagioclase and less common ferromagnesian material in a glassy groundmass. The latter has devitrified, with relict perlitic cracking being present and there are also zones of brecciation. The rock has undergone pervasive, strong alteration, with replacement of groundmass material by K-feldspar, albite and minor quartz, chlorite, sericite and porphyroblastic carbonate. Plagioclase phenocrysts have been albitised and ferromagnesian grains largely replaced by quartz and carbonate.

378187 TS

Summary: Strongly altered, porphyritic intermediate to felsic volcanic rock, perhaps representing a lava. There is no textural evidence for the sample to represent a clastic rock, e.g. epiclastic sandstone. The original rock contained a few phenocrysts of feldspar (probably plagioclase) and a ferromagnesian phase, plus a little FeTi oxide, set in a fine grained, perhaps glassy, quartzofeldspathic groundmass. The latter might contain possible spheroidal devitrification structures. Feldspar and ferromagnesian phenocrysts have been replaced by sericite and quartz, with groundmass material having recrystallised to an assemblage of K-feldspar, quartz, sericite and minor hematite. In places, quartz aggregates form cores to the spheroidal structures. The altered rock has been cut by a few extensional quartz-rich veins containing a few aggregates of sericite. These veins might also have hosted aggregates of pyrite, but the latter has been replaced by goethite as a result of weathering.

378188 TS

Summary: Strongly altered, medium grained lithic sandstone. The rock is dominated by finely recrystallised lithic detrital grains (mostly fine grained sedimentary material such as siliceous argillite and minor chert, but with a few possible altered volcanic lithics). There is a minor population of detrital quartz grains. The rock has undergone phyllic alteration, with strong replacement of finer matrix material and possible volcanic lithic grains by sericite and minor quartz. There has also been slight development of quartz-rich aggregates and veinlets. The rock may have contained a few grains of pyrite as part of the alteration assemblage, but pyrite has since been replaced by goethite as a result of weathering.

378189 TS

Summary: Coarse grained lithic sandstone, grading to conglomerate (or could be termed a sedimentary breccia), with abundant fine grained sedimentary lithic clasts (finely recrystallised chert and siliceous argillite), cemented by fine grained hematite and minor fine to medium grained crystalline quartz. There is no evidence that the hematite has replaced former pyrite or Fe-bearing carbonate. Subsequent to hematite deposition, there has been minor veining by carbonate. The sample differs from 378109 in the fact that it contains less diversity in lithic grains, has essentially no individual detrital mineral grains and has abundant hematite cement.

The following table provides a summary classification of the samples examined. Many samples are difficult to accurately classify into a genetic type, but the most likely interpretations are displayed.

Clastic sedimentary	Epiclastic	Pyroclastic	Extrusive (lava)	Intrusive
378105	378104	378103	378119	378107
378106	378112	378110	378121	378114
378108	378120	378115	378125	378126
378109	378128	378116	378127	378129
378111	378137	378139	378130	378142
378113	378141	378140	378131	378143
378118	378146	378145	378132	378144
378138	378147	378151	378133	378157
378164	378150	378152	378135	378158
378165	378153	378167	378136	378159
378166	378163	378173	378148	378161
378188	378168	378176	378149	378162
378189	378184		378154	378174
			378155	378177
			378156	378180
			378160	378182
			378175	378183
			378178	
			378179	
			378181	
			378185	
			378186	
			378187	

Interpretation and discussion

The distinction between “clastic sedimentary” and “epiclastic” rocks is based on the proportion of juvenile volcanic detritus versus fine grained sedimentary detritus. Sedimentary bedding phenomena have only been recognised in one or two samples and is not diagnostic. Epiclastic rocks have a preponderance of volcanic detrital grains and in the suite display a range from very immature, e.g. tightly packed, angular grains, with strong preservation of delicate volcanic features such as pumice, and in some samples, preservation of primary igneous minerals, such as clinopyroxene. The clastic sedimentary rocks tend to have a preponderance of fine grained sedimentary detritus, ranging from massive to weakly foliated sericitic shale and siltstone (in places carbonaceous) to siliceous argillite to chert. A few samples have relicts of radiolarians in the fine grained sedimentary detrital grains. Several of the clastic sedimentary rocks, as well as a few of the epiclastics, have evidence of siliceous metamorphic detritus, e.g. quartzite

and muscovite quartzite, with many of these grains being foliated. Detrital muscovite flakes also occur in many of these rocks and may have come from a similar metamorphic source (e.g. from the Rocky Cape or Tyennan regions). Three clastic sedimentary samples (378118, 378163, 378165) contain tiny traces of detrital chromite, with the first sample also containing small lithic clasts with fuchsite alteration. These characteristics are consistent with a small ultramafic provenance component.

The distinction between epiclastic and pyroclastic rocks is based on the lack of textural evidence for any sedimentary transport or depositional processes in the latter. Pyroclastic rocks tend to be dominated by tightly packed volcanic fragments, commonly pumiceous, with a few also containing finer grained matrix material that is also pumiceous and commonly displays small former glass shard fragments. It is possible that one or two of the interpreted pyroclastic rocks may be ignimbritic (i.e. welded texture). In addition to volcanic lithic fragments dominated by pumice, pyroclastic rocks also commonly contain a crystal component, e.g. disaggregated volcanic phenocrysts of plagioclase and/or quartz. Epiclastic rocks commonly have less of a pumiceous lithic component and a higher proportion of other volcanic lithics (e.g. porphyritic lava fragments) and/or crystals; they also may contain a higher proportion of matrix material (generally not former glass shards) and may contain lithic grains of fine grained sedimentary material.

There are relatively numerous samples in the suite that are classified as representing intrusive igneous rocks. Most interpreted intrusives are porphyritic and have scattered to abundant phenocrysts occurring in a fine to medium grained holocrystalline groundmass. One or two, however, are less porphyritic, and more evenly medium grained. The main distinction from interpreted extrusives is the grainsize of the groundmass, which in the latter is typically fine grained to possibly glassy in original character. Some of the porphyritic igneous rocks with fine grained groundmass are also amygdaloidal, a common textural characteristic of lavas. However, in the descriptions of several porphyritic igneous samples, the distinction between extrusive and intrusive emplacement modes remains speculative.

In the sample suite as a whole, primary textures are moderately to well preserved, and together with either the preservation of primary minerals (e.g. magmatic minerals) or easily recognisable pseudomorphs thereof, have allowed some degree of certainty about (a) the primary rock types, and (b) their mode of formation. It is likely that there is a large amount of consanguinity between the various igneous rocks in the suite and many of the interpreted epiclastic sedimentary rocks, and that this relationship could extend further into many of the recognised clastic sedimentary rocks, i.e. with decreasing detrital volcanic material and an increasing amount of fine grained sedimentary (or metasedimentary) detritus. Many of the sedimentary rocks

have a clear “mixed” provenance, e.g. with evidence of juvenile volcanic detritus as well as sedimentary or metasedimentary detritus.

The igneous rocks in the suite (i.e. interpreted intrusives, extrusives and pyroclastics) mostly fall into a compositional spectrum from intermediate to felsic. Only one rock with a mafic igneous composition has been recognised (378114). Interpreted intrusive rocks are largely porphyritic and span the compositional range from monzodioritic to granodioritic; some intrusives having finer grained groundmasses are assigned “volcanic” nomenclature such as latite or rhyodacite – perhaps the latter types could be given less genetic terms such as plagioclase-clinopyroxene porphyry or quartz-feldspar porphyry. From the textural characteristics, most of the interpreted intrusives are considered to have been emplaced rather shallowly in the earth’s crust and are likely therefore to represent sub-volcanic masses. Interpreted extrusive rocks span the composition range from latite (or high-K andesite) to rhyodacite, although in a few, the intensity of imposed alteration makes identification of primary rock type rather obscure. Most interpreted pyroclastic rocks are felsic in composition, although a few might tend to grade towards intermediate volcanic composition. Derived epiclastic sedimentary rocks are considered to cover the same composition spectrum as the igneous rocks, i.e. from being dominated by intermediate igneous detritus such as porphyritic latite, to felsic igneous detritus, e.g. porphyritic rhyodacite.

Many of the volcanic and intrusive rocks either preserve primary igneous minerals or contain pseudomorphs that indicate the nature of the primary mineralogy. Most igneous rocks contain evidence of plagioclase crystallisation (commonly as a phenocryst and a groundmass phase) and plagioclase (or its alteration products) is usually the dominant mineral. Quartz occurs as a phenocryst phase in many of the felsic extrusive and pyroclastic rocks, and as a derived detrital grain phase in some epiclastics. In some of the coarser intrusives, it is present as an interstitial, late-magmatic phase. Quartz is also a common groundmass phase in some of the more felsic volcanic rocks. K-feldspar commonly occurs as a fine grained groundmass phase, but in some of the coarser intrusives, it occurs interstitially as a late-magmatic phase. It is probable that ferromagnesian minerals (one or more) occurred in most igneous samples and also occurred in some of the epiclastic rocks as detrital grains. However, except in a few samples, all ferromagnesian phases have been completely altered. Clinopyroxene phenocrysts have been preserved in a few igneous rocks (e.g. porphyritic latite) and detrital clinopyroxene grains occur in one or two of the epiclastics. Brown hornblende and biotite are preserved very rarely, although it is probable that biotite may have been a relatively common ferromagnesian phenocryst phase in several of the more felsic igneous rocks, judging by relict grain shapes. Pyroxene (presumably clinopyroxene) would have also been a common phenocryst phase. Microphenocrysts of FeTi oxide occur in many igneous rocks and

detrital grains occur in many epiclastics. The magnetic characteristics of many samples indicate that this phase is magnetite, or more specifically, titanomagnetite. Other minor to trace accessory minerals noted in the igneous rocks and in derived epiclastics include apatite, zircon and possibly, rare titanite.

A common mineralogical thread through many of the less altered igneous rocks and the derived epiclastics, is the presence of interpreted magmatic K-feldspar. In many rocks containing K-feldspar, there is little or no evidence for this phase to have been formed by hydrothermal replacement (i.e. a form of potassic alteration), notwithstanding the possibility of alkali (e.g. K) mobility during diagenesis, hydrothermal alteration and/or later imposed metamorphism. As a consequence, it is interpreted that the igneous rock suite overall has a probable high-K, calc-alkaline signature. Clearly, the magmatic affinities are of I-type, as indicated by the presence at the magmatic stage of minerals such as clinopyroxene, (titano)magnetite and uncommon hornblende.

All samples in the suite display evidence of alteration. Generally, the effects are pervasive and there is little indication of fracture control on alteration assemblages. The terminology used to describe and classify different alteration assemblages is that used for hydrothermal alteration (e.g. propylitic, phyllic, potassic, sodic), but it is recognised that many of the samples may not have undergone significant hydrothermal alteration, but been subject instead to the effects of very low grade (regional) metamorphism. The mineralogical consequences may ultimately be the same, but there is a difference in fluid:rock ratio and time.

The types of alteration observed fall into the above-mentioned categories, i.e. propylitic, phyllic, potassic, sodic, and there are also transitional varieties. The alteration effects are interpreted to be the result of either, or both, very low grade metamorphism or hydrothermal alteration, with the latter inferring a high fluid:rock ratio and a significant compositional change in relation to primary rock composition. However, it is acknowledged that the two processes overlap, especially in an active volcanic and volcano-sedimentary environment such as in the Mount Read Volcanics, where seawater interaction could have been extensive at the magmatic and diagenetic stages.

Propylitic alteration assemblages typically involve albite and chlorite, with rather common carbonate (ranging from Fe-bearing, e.g. ankerite, siderite to calcite) and sericite, and less common epidote. Leucoxene/rutile and pyrite are common trace to minor accessories and titanite is rare. A few samples demonstrate formation of actinolite and/or pumpellyite as part of this alteration assemblage. Although propylitic alteration could be a result of focussed hydrothermal processes, it more likely reflects widespread very low grade metamorphic effects. Phyllic alteration assemblages are typified by

sericite + quartz, commonly with leucoxene/rutile and a trace of pyrite, but in places they contain carbonate (as porphyroblasts) and grade into propylitic assemblages with increasing chlorite and albite. One sample (378131) has a variant of phyllic alteration in that it contains a few thin tourmaline-quartz-pyrite veins and a trace of alteration-derived tourmaline with sericite. Phyllic alteration more likely reflects focussed hydrothermal processes. Many samples have assemblages that could be viewed as being transitional from propylitic to potassic, or phyllic to potassic, due to the presence of K-feldspar in addition to many of the phases described above. However, it is difficult to distinguish whether much of the fine grained K-feldspar present is actually relict magmatic, or whether it might have replaced earlier phases. From study of the least-altered samples in the suite, the view is taken that much of the K-feldspar encountered may be relict, although there is probably mobilisation of K and formation of "secondary" K-feldspar in some samples. Sodic alteration occurs in a few samples and is manifest by the abundance of albite (e.g. having replaced former feldspars), in places in association with appreciable chlorite. Sodic alteration may reflect stronger focussing of heated seawater into the alteration system. Minor hematite occurs in several samples, generally as part of propylitic or phyllic alteration assemblages (e.g. in 378108, 378127, 378148, 378149, 378189) and reflects alteration occurring under rather oxidising conditions. Transitional alteration assemblages are widespread in the sample suite, with variations between propylitic-phyllic, sodic-propylitic, propylitic-potassic, etc.

Veining only occurs significantly in a few samples. Some could have formed hydrothermally at the time of pervasive alteration, but other vein assemblages appear to have been imposed later. Hydrothermal veining occurs in a few samples and could be manifest for example by quartz (-chlorite-carbonate-epidote) infilling (e.g. in 378175) and by tourmaline-quartz-pyrite infill in 378131. Other vein assemblages, although hydrothermal, may be related directly to very low grade metamorphic mobilisation of components, and typified by assemblages containing one or more of the minerals carbonate, chlorite, quartz, albite, sericite and epidote.

As mentioned, some of the alteration observed may be the result of extensive very low grade metamorphism. The propylitic assemblages are essentially consistent with having formed under lower greenschist facies conditions (e.g. chlorite grade), but the presence of pumpellyite in a few samples (378147, 378175, 378176, 378180, 378185) implies that the metamorphic grade may not have attained greenschist facies (at least in some of the sampled areas) but only pumpellyite-actinolite facies.

Penetrative deformation effects are generally not apparent, but in a few samples, the following deformation effects are observed: (a) as foliated metasedimentary lithic grains in clastic sedimentary rocks, and (b) as weak foliation imposed during or following alteration. Obviously in (a), the

deformation in the lithic grains occurred prior to incorporation of the lithic grains into the clastic sedimentary rock and relate to deformation in the source basement terrain. In (b), however, weak deformation effects were imposed after deposition of the rock and are generally indicated by weak foliation defined by preferred orientation of alteration-derived layer silicate phases such as sericite or chlorite. Rarely, thin stylolites occur and are also an indication of penetrative deformation and rock dissolution.

There are few indications of sulphide mineralisation in the sample suite, although traces of fine grained disseminated pyrite occur in many samples. Pyrite is interpreted to have formed as part of the alteration assemblages. Traces of fine grained disseminated sphalerite are recognised in 378103 and 378105, and in the latter sample, there are also traces of fine grained chalcopyrite and pyrrhotite. Again, these latter sulphides are viewed as having formed as part of the respective alteration assemblages.

Since it is understood that the samples in the suite were collected from surface outcrops, it is not surprising that minor effects of weathering are present in many samples. Weathering effects are mainly manifest by the development of a little goethite staining and in the local replacement of minerals such as pyrite and Fe-bearing carbonate by aggregates of goethite. In other samples, there has also been some retrograde degradation of alteration-derived layer silicates. This is commonly expressed in the partial replacement of chlorite by nontronitic clay and by the replacement of sericite by illite or kaolinite. The relatively abundant hematite that occurs in samples 378108, 378127, 378148, 378149 and 378189 is not considered to be due to weathering, but represents a hydrothermal/diagenetic, etc. alteration product.

INDIVIDUAL SAMPLE DESCRIPTIONS

378103 TS

Summary: Coarse grained lithic-crystal felsic tuff, with abundant tightly packed, angular lithic and mineral grains. There is no diagnostic textural evidence to indicate that the rock represents a reworked pyroclastic, i.e. a coarse epiclastic sandstone. Lithic fragments are dominated by volcanic material (mostly pumice, glassy and porphyritic grains), with a tiny population of fine grained carbonaceous sedimentary material. Individual mineral grains are dominated by volcanic-derived quartz and plagioclase, but there are a few small, altered ferromagnesian grains. The matrix is fine to medium grained and composed of altered pumiceous material. The rock has undergone strong alteration of sodic-propylitic type, with dominant replacement by albite, with patchy chlorite and a little quartz, sericite plus trace leucoxene, pyrite and sphalerite.

Handspecimen: The sample is composed of a rather massive, coarse grained lithic-crystal felsic tuff or derived coarse epiclastic sandstone. It is probably of felsic volcanic composition. There are abundant altered lithic clasts of possible volcanic type up to 5 mm across, as well as individual mineral grains up to 4 mm across. The latter are quartz and altered plagioclase. The lithic and mineral grains occur in a finer grained grey matrix. The rock may have undergone some alteration to chlorite and sericite, and testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The rock is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict medium to coarse grained relict clastic texture is moderately well preserved. The rock contains relatively tightly packed individual mineral grains and lithic fragments up to 4 mm across. Interstitially, there is a subordinate fine to medium grained matrix component, now strongly altered. Lithic fragments are angular and dominated by volcanic materials. These include former pumice, vitric material (with rare relict perlitic cracking) and porphyritic material (plagioclase phenocrysts in a fine grained groundmass). There are one or two small fine grained sedimentary lithic grains that are probably carbonaceous shale in composition. Individual mineral grains are dominated by volcanic-derived quartz and altered plagioclase, but there are also a few small grains of altered ferromagnesian material and FeTi oxide. The matrix is apparently composed of small pumiceous fragments, including pseudomorphs after former glass shards. There is no preserved diagnostic texture to indicate sedimentary transport and deposition of components in the sample. Consequently, it is tentatively interpreted that the sample is a pyroclastic, i.e. a coarse felsic lithic-crystal tuff, rather than representing a volcanoclastic sandstone.

b) Alteration and structure: The rock has sustained strong, pervasive alteration, maybe as a result of very low grade metamorphism and/or interaction with heated fluids such as seawater. All plagioclase has been albitised and also slightly flecked by sericite. Most volcanic lithic material and matrix has been replaced by fine to medium grained albite, with minor chlorite, quartz and trace leucoxene, clinozoisite and pyrite. However, some glassy and frothy pumiceous fragments have been largely replaced by chlorite. Former ferromagnesian grains have been replaced by chlorite \pm quartz \pm traces of leucoxene, sphalerite and pyrite, and igneous FeTi oxide grains have been replaced by leucoxene. The alteration is considered to be of sodic type, transitional into propylitic.

c) Mineragraphy and paragenesis: The sample contains a trace of disseminated pyrite and sphalerite as part of the alteration assemblage. Largest grains of each sulphide are up to 0.2 mm across.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 60%, quartz 25%, chlorite 13%, sericite 1% and traces of carbonaceous material, leucoxene, clinozoisite, pyrite and sphalerite.

Interpretation and Comments: It is interpreted that the sample is an altered coarse grained lithic-crystal felsic tuff, with abundant tightly packed, angular lithic and mineral grains. There is no diagnostic textural evidence to indicate that the rock represents a reworked pyroclastic, i.e. a coarse epiclastic sandstone. Lithic fragments are dominated by volcanic material (mostly pumice, glassy and porphyritic grains), with a few grains of fine grained carbonaceous sedimentary material. Individual mineral grains are dominated by volcanic-derived quartz and plagioclase, but there are a few small, altered ferromagnesian grains. The matrix is fine to medium grained and composed of altered pumiceous material. The rock has undergone strong alteration of sodic-propylitic type, with replacement by dominant albite, plus patchy chlorite and a little quartz, sericite plus trace leucoxene, pyrite and sphalerite.

378104 TS

Summary: Coarse grained lithic sandstone, grading into conglomerate, with a wide variety of lithic and individual mineral grain types. Detrital grains are tightly packed and there is little matrix. Lithic grains include fine grained sedimentary/metasedimentary types (e.g. shale, carbonaceous shale, siltstone, siliceous argillite/chert, marble) and fine to medium grained mafic to intermediate igneous types (e.g. intermediate to mafic porphyritic lava, dolerite). Individual mineral grains include plagioclase, quartz, clinopyroxene, calcite and FeTi oxide. The rock has undergone only weak alteration, with relatively minor replacement by albite, chlorite, carbonate and traces of leucoxene and pyrite.

Handspecimen: The sample is composed of a massive, grey coarse grained lithic sandstone, grading into conglomerate. It is dominated by tightly packed angular to sub-rounded detrital grains of fine grained sedimentary material, probably including chert, shale and almost black carbonaceous shale. There may also be a small population of volcanic and carbonate grains. There is little obvious alteration, although a little disseminated pyrite is present. Staining of the section offcut with sodium cobaltinitrite showed that some lithic grains contained a moderate amount of K-feldspar. The rock is weakly magnetic, with susceptibility up to 50×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is well preserved. There are abundant tightly packed angular to sub-rounded lithic detrital grains up to 5 mm across and a smaller population of smaller (up to 0.8 mm) individual mineral grains. There is very little interstitial matrix. Lithic grain compositions are diverse. They include fine grained sedimentary and metasedimentary types, e.g. fine grained recrystallised chert, fine to medium grained quartzite (with trace sericite and biotite and locally with quartz veining), fine grained siliceous argillite, grading into shale (composed of quartz, with variable amounts of sericite, K-feldspar, carbonate and carbonaceous material), volcanoclastic siltstone and recrystallised limestone (marble). Lithic grains also include igneous material, e.g. intermediate to mafic porphyritic volcanic rock (maybe latite, andesite and basalt composition, with plagioclase and clinopyroxene phenocrysts) and relatively fresh medium grained dolerite (composed of plagioclase, clinopyroxene and a little FeTi oxide). Individual detrital mineral grains include plagioclase, clinopyroxene and rare quartz, microcline, FeTi oxide and carbonate. The composition of the rock is consistent with it being a coarse grained lithic sandstone, grading to conglomerate. It has a mixed sedimentary/metasedimentary and intermediate to mafic igneous provenance.

b) Alteration and structure: Alteration is relatively weak and may be a consequence of burial metamorphism. Some of the igneous lithic grains contain relatively fresh plagioclase and clinopyroxene. There has been local replacement of igneous lithic grains by chlorite and a little carbonate, with FeTi oxide being partly altered to leucoxene. Igneous lithic grains may have some albitisation of plagioclase and development of sericite. A little carbonate may have formed in interstitial positions between detrital grains. A trace of pyrite has formed as a result of alteration and occurs disseminated within some lithic grains.

c) Mineragraphy and paragenesis: The sample contains a trace of disseminated pyrite as part of the alteration assemblage. Largest grains are up to 0.3 mm across.

Mineral Mode: Approximate modal proportions are: plagioclase (including albite) and quartz each 35%, chlorite 8%, K-feldspar, clinopyroxene, carbonate and sericite each 5%, carbonaceous material 1% and traces of pyrite, leucoxene, biotite and FeTi oxide.

Interpretation and Comments: It is interpreted that the sample is a coarse grained lithic sandstone, grading into conglomerate. It tightly packed detrital lithic and mineral grains and little matrix. Lithic grains include fine grained sedimentary/metasedimentary types (e.g. shale, carbonaceous shale, siltstone, siliceous argillite/chert, marble) and fine to medium

grained mafic to intermediate igneous types (e.g. intermediate to mafic porphyritic lava, dolerite). Individual mineral grains include plagioclase, quartz, clinopyroxene, calcite and FeTi oxide. The rock has undergone only weak alteration, with relatively minor replacement by albite, chlorite, carbonate and traces of leucoxene and pyrite.

378105 TS

Summary: Coarse grained lithic sandstone, with a wide variety of lithic and individual mineral grain types. Detrital grains are tightly packed with only a little matrix. Lithic grains include fine grained sedimentary/metasedimentary types (e.g. shale, carbonaceous shale, siliceous argillite/chert, recrystallised limestone) and fine to medium grained mafic igneous types (e.g. basaltic porphyritic lava, dolerite). Individual mineral grains include plagioclase, quartz, clinopyroxene, calcite and altered ferromagnesian material. The rock has undergone only weak alteration, with relatively minor replacement by albite, chlorite, carbonate, sericite and traces of leucoxene, sphalerite, pyrrhotite, chalcopyrite and pyrite.

Handspecimen: The sample is composed of a massive, grey coarse grained lithic sandstone. It is dominated by tightly packed angular to sub-rounded detrital grains up to 7 mm across of fine grained sedimentary material, probably including chert, shale and almost black carbonaceous shale. There may also be a small population of volcanic and carbonate grains. Alteration is minor apart from possible formation of minor carbonate and chlorite, and the crystallisation of a little disseminated pyrite. Staining of the section offcut with sodium cobaltinitrite showed that some lithic grains contained a moderate amount of K-feldspar. The rock is weakly magnetic, with susceptibility up to 40×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is well preserved. There are abundant tightly packed angular to sub-rounded lithic detrital grains up to 7 mm across and less abundant, smaller (up to 1 mm) individual mineral grains. There is only a little interstitial matrix. Lithic grain compositions are diverse. They include fine grained sedimentary and metasedimentary types, e.g. polycrystalline quartz representing fine grained recrystallised chert, fine to medium grained quartzite, locally with quartz veining, fine grained siliceous argillite, grading into shale (composed of quartz, with variable amounts of sericite, K-feldspar, carbonate and carbonaceous material) and recrystallised limestone. There are also igneous derived lithic grains e.g. mafic porphyritic volcanic rock (e.g. basaltic, with plagioclase and clinopyroxene phenocrysts) and relatively fresh medium grained dolerite (composed of plagioclase, clinopyroxene and a little FeTi oxide) and a little altered felsic igneous rock (fine to medium grained, with quartz, plagioclase and K-feldspar). Individual detrital mineral grains include plagioclase, clinopyroxene and rare quartz, altered ferromagnesian material, FeTi oxide and carbonate. The matrix interstitial to the detrital grains is fine grained and perhaps represents former muddy to silty material. It has been recrystallised. The relict texture and grain composition indicate that the rock is a coarse grained lithic sandstone. It has a mixed sedimentary/metasedimentary and mafic to felsic igneous provenance.

b) Alteration and structure: Alteration is relatively weak and may be a consequence of burial metamorphism. Some of the igneous lithic grains contain relatively fresh plagioclase and clinopyroxene, although there has been local alteration to chlorite, albite and sericite. Some igneous lithic grains and former ferromagnesian grains have been replaced by chlorite and a little carbonate, with FeTi oxide being partly altered to leucoxene. Plagioclase grains are partly albitised with minor development of sericite and carbonate. A little carbonate and chlorite may have formed in interstitial positions between detrital grains, with carbonate also occurring as uncommon porphyroblastic masses up to 1 mm across. Rare grains of sulphides occur in the partly altered lithic grains and matrix as part of the alteration assemblage. Sulphides include sphalerite, pyrrhotite, chalcopyrite and pyrite.

c) Mineragraphy and paragenesis: The sample contains traces of irregularly disseminated sphalerite, pyrrhotite, chalcopyrite and pyrite as part of the alteration assemblage. Largest grains (sphalerite) are up to 0.3 mm across.

Mineral Mode: Approximate modal proportions are: plagioclase (including albite) and quartz each 35%, chlorite 8%, K-feldspar, clinopyroxene, carbonate and sericite each 5%, carbonaceous material 1% and traces of pyrite, leucoxene and FeTi oxide.

Interpretation and Comments: It is interpreted that the sample is a weakly altered coarse grained lithic sandstone, with a wide variety of lithic and individual mineral grain types. Detrital grains are tightly packed with only a little matrix interstitially. Lithic grains include fine grained sedimentary/metasedimentary types (e.g. shale, carbonaceous shale, siliceous argillite/chert, recrystallised limestone) and fine to medium grained mafic igneous types (e.g. basaltic porphyritic lava, dolerite). Individual mineral grains include plagioclase, quartz, clinopyroxene, calcite and altered ferromagnesian material. There has been relatively minor replacement by albite, chlorite, carbonate, sericite and traces of leucoxene, sphalerite, pyrrhotite, chalcopyrite and pyrite.

378106 TS

Summary: Moderately weathered, medium grained lithic-quartz sandstone. The detrital lithic grains and mineral grains are rather tightly packed and there is only minor matrix. Weak bedding laminations are locally present. The lithic detrital grains include a substantial fine grained sedimentary component (shale, siltstone, chert and quartzite grains) as well as a fine grained altered volcanic component. The rock has undergone moderate to strong alteration, with replacement of lithic and plagioclase grains and the matrix. The alteration assemblage is dominated by chlorite and sericite, with minor albite and quartz. Weathering effects have been imposed, leading to extensive goethite staining.

Handspecimen: The sample is composed of a massive to weakly laminated, orange-brown, moderately weathered medium grained sandstone, containing considerable lithic and quartz grains. Bedding is defined by slight variations in detrital grain size. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The rock contains a little detrital magnetite as it is moderately magnetic, with susceptibility up to 310×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is moderately well preserved and there is local bedding laminae, defined by variations in detrital grain size. The rock contains angular to sub-rounded detrital grains up to 2 mm across, with the detrital grains being dominated by fine grained lithics and quartz, but there are a few grains of plagioclase, muscovite, FeTi oxide (e.g. titanomagnetite) and rare biotite. Lithics are of mixed provenance. They include fine grained clastic sedimentary rock (e.g. sericitic shale and siltstone, and quartzite) as well as rare grains of chert. There are also relatively abundant fine grained altered volcanic lithic grains – most have little recognisable relict texture, but some were evidently feldspar-phyric. There are also rare small bright green grains, composed of celadonite that might represent altered volcanic material. The detrital grains are relatively tightly packed and there is only a small matrix component, probably originally of muddy-silty material, but now totally altered. The relict texture suggests that the rock is a medium grained lithic-quartz sandstone (greywacke) of mixed fine grained sedimentary and volcanic provenance. The volcanic material is speculated to be of intermediate composition.

b) Alteration and structure: The rock has undergone moderate to strong alteration and subsequent weathering effects. Lithic volcanic grains have been altered to chlorite, sericite and possible albite and quartz, with shaly-silty sedimentary lithic grains being mostly composed of sericite and quartz. Former plagioclase grains have been albitised and the matrix largely replaced by chlorite and sericite. Detrital FeTi oxide grains are partly replaced by goethite and leucoxene. The alteration assemblage is of propylitic type and has been overprinted by weathering effects, manifest by extensive staining by goethite (especially of the layer silicates) and formation of scattered small goethite aggregates.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There is a trace of relict detrital FeTi oxide.

Mineral Mode: Approximate modal proportions are: chlorite and sericite each 30%, quartz 25%, plagioclase (albite) 10%, goethite 4% and traces of FeTi oxide, leucoxene and celadonite.

Interpretation and Comments: It is interpreted that the sample represents a medium grained, weakly laminated, lithic-quartz sandstone (greywacke) with a mixed fine grained sedimentary and volcanic provenance. The detrital lithic grains and mineral grains are rather tightly packed and there is only minor matrix. The lithic detrital grains include a substantial fine grained sedimentary component (shale, siltstone, chert and quartzite grains) as well as a fine grained altered volcanic component. The rock has undergone moderate to strong propylitic alteration, with replacement of lithics and plagioclase grains and the matrix. The

alteration assemblage is dominated by chlorite and sericite, with minor albite and quartz. Weathering effects have been imposed, leading to extensive goethite staining.

378107 TS

Summary: Porphyritic quartz latite or quartz micromonzonite with pervasive, strong propylitic alteration. The rock originally contained phenocrysts of plagioclase and less common ferromagnesian grains (e.g. pyroxene, hornblende), as well as a few glomeroporphyritic aggregates of plagioclase-ferromagnesian-FeTi oxide in a fine to medium grained inequigranular groundmass dominated by K-feldspar, plagioclase and quartz. Alteration has led to development of an alteration assemblage of albite, chlorite and epidote, with a little actinolite.

Handspecimen: The sample is composed of a massive, porphyritic, fine to medium grained intermediate to felsic igneous rock. There are scattered tabular plagioclase phenocrysts up to 5 mm across and altered ferromagnesian patches (replaced by dark green chlorite and yellowish epidote) in a fine to medium grained grey-pink feldspathic groundmass. Staining of the section offcut with sodium cobaltinitrite showed that there was abundant K-feldspar in the groundmass. The rock contains a little disseminated magnetite and is moderately magnetic, with susceptibility up to 570×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. The rock is strongly and pervasively altered, but preserves pseudomorphs after former tabular plagioclase phenocrysts up to 3 mm across and a few smaller altered ferromagnesian phenocrysts up to 1.5 mm across. Glomeroporphyritic aggregates up to several millimetres across would have originally been composed of plagioclase, ferromagnesian and FeTi oxide (titanomagnetite). The rock also contains a few dispersed microphenocrysts of FeTi oxide up to 0.5 mm across. Judging by relict grain shapes, the ferromagnesian material might have included pyroxene and hornblende. The phenocrystal phases occur in a fine to medium grained inequigranular groundmass, with abundant K-feldspar, subordinate plagioclase and interstitial quartz, minor altered ferromagnesian material and a little FeTi oxide. In the groundmass, interstitial quartz grains are up to 1 mm across. From the relict texture and interpreted primary mineralogy, the rock is considered to represent a porphyritic quartz latite or quartz micromonzonite. It may have been emplaced as a shallow intrusive.

b) Alteration and structure: Strong pervasive alteration has been imposed and it is of propylitic type, perhaps as a result of hydrothermal action and/or very low grade metamorphism. All plagioclase has been albitised and further replaced by fine grained epidote and minor chlorite. All ferromagnesian material has been replaced by aggregates of fine to medium grained epidote, chlorite and minor actinolite, and FeTi oxide is slightly replaced by leucoxene.

c) Mineragraphy and paragenesis: No sulphide minerals have been observed. The rock retains a little relict igneous FeTi oxide.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 40%, K-feldspar 35%, quartz 11%, chlorite 7%, epidote 5%, actinolite and FeTi oxide each 1% and a trace of leucoxene.

Interpretation and Comments: It is interpreted that the sample represents a porphyritic quartz latite or quartz micromonzonite, perhaps emplaced as a shallow intrusive. It exhibits pervasive, strong propylitic alteration. The rock originally contained phenocrysts of plagioclase and less common ferromagnesian grains (e.g. pyroxene, hornblende), as well as a few glomeroporphyritic aggregates of plagioclase-ferromagnesian-FeTi oxide in a fine to medium grained inequigranular groundmass dominated by K-feldspar, plagioclase and quartz. Alteration has led to development of an alteration assemblage of albite, chlorite and epidote, with a little actinolite.

378108 TS

Summary: Medium grained lithic-quartz-feldspar sandstone (greywacke), with moderate to strong alteration of propylitic type. The rock has abundant detrital lithic grains (mostly fine grained sedimentary types, but with a small mafic to intermediate igneous grain population) along with detrital plagioclase, quartz and a little altered ferromagnesian material and FeTi oxide. Alteration has led to local replacement by albite, chlorite, carbonate, sericite and hematite and has evidently occurred under rather oxidising conditions, perhaps related to very low grade metamorphism.

Handspecimen: The sample is composed of a massive, medium grained dark grey sandstone, locally with a few red-brown spots perhaps due to hematite pigmentation. The detrital grain texture is well preserved and it is evident that there is a large amount of lithic grains along with feldspar and quartz. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The rock contains a little disseminated magnetite and is moderately magnetic, with susceptibility up to 380×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. The rock is dominated by tightly packed angular to sub-rounded detrital grains up to 1.5 mm across. Detrital grains are dominated by lithics, although there is also a substantial amount of detrital plagioclase (mostly altered) and quartz, with a minor amount of altered ferromagnesian grains, FeTi oxide and traces of detrital muscovite and tourmaline. Lithic grains are dominated by fine grained sedimentary material that appears to include shaly material (e.g. fine grained sericite \pm quartz \pm chlorite) and cherty or siliceous argillite material (fine grained polycrystalline quartz aggregates \pm sericite) as well as a few carbonate-rich grains. There are also a few igneous lithic grains, including fine to medium grained altered doleritic material and possible intermediate to mafic volcanic material. There is only a minor matrix component between the detrital grains and it appears to have been silty to muddy material. Relict textures suggest that the rock is a medium grained lithic-quartz-feldspar sandstone (greywacke) with a mixed sedimentary and volcanic provenance.

b) Alteration and structure: The rock has undergone moderate to strong pervasive alteration. Some detrital plagioclase and that in igneous lithic grains has been albitised as well as being replaced by carbonate and sericite. Sedimentary lithic grains are composed of sericite, quartz, in places with albite, chlorite, carbonate and hematite, and igneous grains are mostly replaced by albite, chlorite, carbonate and hematite. Detrital FeTi oxide grains have been partly altered to hematite and leucoxene. In the matrix, there has been minor development of chlorite and carbonate. Alteration is of propylitic type and probably developed under oxidising conditions.

c) Mineragraphy and paragenesis: No sulphide minerals have been observed. The rock retains a little relict igneous FeTi oxide.

Mineral Mode: Approximate modal proportions are: plagioclase (including albite) 40%, quartz 25%, chlorite 18%, carbonate 9%, sericite/muscovite 5%, hematite 2%, FeTi oxide 1% and a trace of leucoxene and tourmaline.

Interpretation and Comments: It is interpreted that the sample is a medium grained lithic-quartz-feldspar sandstone (greywacke), with a mixed sedimentary and igneous provenance. The rock has abundant detrital lithic grains (mostly fine grained sedimentary types, but with a small mafic to intermediate igneous grain population) along with detrital plagioclase, quartz and a little altered ferromagnesian material and FeTi oxide. Alteration is of moderate to strong propylitic type and has led to local replacement by albite, chlorite, carbonate, sericite and hematite. It has occurred under rather oxidising conditions, perhaps related to very low grade metamorphism.

378109 TS

Summary: Coarse grained lithic-quartz sandstone, grading into conglomerate. Most coarse detrital clasts are composed of fine grained sedimentary material, dominated by hematite-pigmented shale, siliceous argillite and chert (some being radiolarian). There are also a few siltstone, quartzite and altered porphyritic ?mafic volcanic clasts. The rock also has a large population of smaller discrete sand-sized mineral grains, mostly quartz, but with minor plagioclase and a little muscovite. A small silty to muddy matrix component has been altered and recrystallised. The rock has sustained weak deformation effects, leading to development of a weak foliation. Alteration effects, with development of sericite, carbonate, chlorite and minor amounts of hematite and a clay phase may be due to very low grade metamorphism.

Handspecimen: The sample is composed of a weakly foliated coarse grained lithic sandstone, grading into conglomerate. It contains abundant elongate fine grained clasts of hematite-pigmented shale and lesser amounts of chert that are brick-red to pink and pale grey in colour. The largest clasts are up to 1.5 cm across. The coarser clasts occur in a sandy matrix in which quartz is abundant. Foliation is defined by preferred orientation of elongate lithic clasts. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The rock is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the rock has a well preserved relict medium to coarse grained relict detrital grain texture. It is dominated by large (up to 1 cm) irregular to elongate and angular to sub-rounded lithic clasts, but there is also a large population of smaller detrital grains (e.g. <3 mm across) of lithics and individual mineral grains, plus a minor matrix component. Lithic grains are varied, but are dominated by fine grained massive to weakly foliated hematite-pigmented shale, grading to siliceous argillite (assemblages of sericite, quartz and minor hematite) and to chert (partly recrystallised and dominated by quartz and minor hematite, with some clasts containing recrystallised radiolarians). These fine grained sedimentary lithic clasts make up the majority of lithics, but there is a small amount of siltstone (composed of detrital quartz, muscovite, plus minor carbonate and hematite), fine to medium grained quartzite and strongly altered porphyritic volcanic rock, perhaps originally of mafic to intermediate composition. The latter would have had scattered plagioclase grains, but have been subsequently replaced by sericite, hematite, albite, a clay phase and traces of leucoxene. The rock also contains a considerable amount of discrete mineral grains up to 1.5 mm across. These are dominated by quartz, but there is a smaller amount of altered plagioclase, a little muscovite and traces of FeTi oxide, zircon and biotite. Detrital components of the rock are enclosed in a small amount of matrix. The latter would have been silty to muddy and has been altered and recrystallised. The relict characteristics of the sample indicate that it is a lithic-quartz sandstone, grading into conglomerate, with a lithics having a dominant fine grained sedimentary source.

b) Alteration and structure: The rock has undergone moderate alteration and weak deformation effects, probably as a result of very low grade metamorphism. Matrix material has been recrystallised to a sericite-rich assemblage, with local carbonate, chlorite, quartz and a little hematite. Detrital plagioclase and plagioclase hosted in volcanic lithic grains has been variably altered to albite, clay, sericite and carbonate, and former detrital FeTi oxide grains have been replaced by hematite. A few carbonate porphyroblastic masses up to 2.5 mm across have grown across matrix and detrital grain components. Although many sedimentary lithic clasts are pigmented by hematite, it is interpreted that the hematite was present prior to incorporation of the clasts into the sandstone/conglomerate. Evidently, alteration was maintained under oxidising conditions in order to have ensured the stability of hematite. Foliation in the sample is defined by preferred orientation of sericitic shaly lithic clasts and by slight preferred orientation of sericite in the recrystallised matrix.

c) Mineralogy and paragenesis: No sulphide minerals have been observed. The rock contains minor hematite irregularly distributed throughout.

Mineral Mode: Approximate modal proportions are: quartz 60%, sericite + muscovite 20%, carbonate 8%, plagioclase (albite) 5%, hematite 4%, chlorite 2%, clay 1% and traces of zircon, biotite and leucoxene.

Interpretation and Comments: It is interpreted that the sample is a coarse grained lithic-quartz sandstone, grading into conglomerate, with a dominant fine grained sedimentary provenance, but with a few volcanic-derived clasts. Most coarse detrital clasts are composed of hematite-pigmented shale, siliceous argillite and chert (some being radiolarian). There are also a few siltstone, quartzite and altered porphyritic ?mafic volcanic clasts. The rock also has a large population of smaller discrete sand-sized mineral grains, mostly quartz, but with minor plagioclase and a little muscovite. A small silty to muddy matrix component has been altered and recrystallised. The rock has sustained weak deformation effects, leading to development of a weak foliation. Alteration effects, with development of sericite, carbonate, chlorite and minor amounts of hematite and a clay phase may be due to very low grade metamorphism.

378110 TS

Summary: Altered fine to medium grained lithic-crystal tuff, with a dominance of pumiceous lithic grains and smaller populations of quartz, feldspar and altered ferromagnesian grains. The rock has been subject to strong replacement, with originally glassy pumiceous material having been totally replaced by fine grained K-feldspar and a smaller amount of quartz, albite and chlorite. The alteration assemblage also contains a little sericite and traces of leucoxene, pyrite and epidote. It is interpreted to be transitional between potassic and propylitic types, and probably a result of very low grade metamorphism.

Handspecimen: The sample is composed of a massive, fine to medium grained, partly altered volcanoclastic rock, e.g. tuff or epiclastic. It is mostly grey in colour, but locally greenish to pinkish. It evidently contains small lithic and feldspar grains. Alteration is likely to have formed dispersed fine grained chlorite. Staining of the section offcut with sodium cobaltinitrite showed that there is abundant K-feldspar throughout. The rock is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict fine to medium grained fragmental texture is moderately well preserved. The rock is dominated by tightly packed altered lithic grains up to 1.5 mm across, with smaller populations of volcanic quartz and feldspar grains up to 1 mm across. The latter probably represent former phenocrystal grains. Feldspar grains include both K-feldspar and plagioclase. The rock also contains a small amount of altered ferromagnesian grains, altered FeTi oxide and relict muscovite and rare biotite. Lithic grains are dominated by former pumiceous material (including frothy material and glass shard fragments), but there is a small amount of probably fine grained sedimentary material (e.g. pelitic). The relict texture and inferences on composition suggest that the rock is dominantly of felsic volcanic origin and may represent a lithic (pumiceous)-crystal tuff. The presence of apparent "detrital" sedimentary lithic grains and trace muscovite and biotite could imply an additional source of components and hence the possibility of reworking via epiclastic processes.

b) Alteration and structure: The original volcanoclastic rock has been subjected to rather strong and pervasive alteration, perhaps as a result of very low grade metamorphism. There has been total replacement of all pumiceous (glassy) material by fine grained K-feldspar, along with minor quartz, albite, chlorite and traces of leucoxene and pyrite. Possible sedimentary lithic grains have been altered to sericite \pm quartz \pm K-feldspar and plagioclase grains have been albitised. Original ferromagnesian material (including some biotite) has been mainly altered to chlorite, but there is also a little sericite and epidote. Former FeTi oxide grains have been altered to leucoxene. The alteration assemblage is interpreted to be transitional between potassic and propylitic in character.

c) Mineralogy and paragenesis: The rock contains a few grains of disseminated pyrite as part of the alteration assemblage. Largest grains are up to 0.2 mm across.

Mineral Mode: Approximate modal proportions are: K-feldspar 50%, plagioclase (albite) 25%, quartz 15%, chlorite 7%, sericite + muscovite 2% and traces of leucoxene, epidote, pyrite and biotite.

Interpretation and Comments: It is interpreted that the sample is an altered fine to medium grained lithic-crystal tuff, with a dominance of pumiceous lithic grains and smaller populations of quartz, feldspar and altered ferromagnesian grains. The rock has been subject to strong replacement, with originally glassy pumiceous material having been totally replaced by fine grained K-feldspar and a smaller amount of quartz, albite and chlorite. The alteration assemblage also contains a little sericite and traces of leucoxene, pyrite and epidote. It is interpreted to be transitional between potassic and propylitic types, probably caused by very low grade metamorphism.

378111 TS

Summary: Coarse grained lithic-feldspathic sandstone, with a mixed provenance of sedimentary and volcanic material. Lithic grains are dominated by massive to weakly foliated shale-siltstone (locally carbonaceous) and intermediate to mafic volcanic material, but with minor quartz-rich metasedimentary material (e.g. quartzite, metachert) and felsic pumiceous material. There are abundant detrital plagioclase grains, with minor quartz and altered ferromagnesian material. There is a minor shale-siltstone matrix component. The rock has undergone moderate alteration, perhaps as the result of very low grade metamorphism, with the partial replacement of lithic and mineral grains, and the matrix, by chlorite, carbonate, sericite and albite. In places, a weak foliation is evident, defined by preferred orientation of chloritised volcanic grains and by incipient carbonaceous stylolites.

Handspecimen: The sample is composed of a massive, grey, coarse grained lithic-feldspathic sandstone, with individual detrital grains up to 5-6 mm across. Many lithic grains are finer grained, dark grey and probably of sedimentary type (perhaps carbonaceous). The rock may have undergone minor alteration to chlorite and carbonate. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The rock is very weakly magnetic, with susceptibility of up to 25×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict coarse detrital grain texture is well preserved. There is a rather tightly packed detrital grain texture, with abundant lithic and mineral grains in a minor fine grained matrix component. Detrital grains are angular, with abundant lithic grains up to 4 mm across. Variably altered plagioclase grains are also abundant and are up to 2.5 mm across. The rock also contains minor amounts of detrital quartz, altered ferromagnesian material and traces of muscovite, microcline and FeTi oxide. Lithic grains are diverse and include massive to weakly foliated fine grained shale grading into siltstone (mostly quartz, sericite, albite, with local carbonaceous material), a few fine grained polycrystalline quartz aggregates, in places with rare muscovite (e.g. metachert, quartzite), porphyritic intermediate to mafic volcanic grains (phenocrysts of plagioclase and altered ferromagnesian material in a fine grained groundmass), aphanitic altered mafic volcanic rock and uncommon felsic pumiceous volcanic grains. In places, there is a minor shaly matrix component in-between the detrital grains. The matrix is slightly carbonaceous and could have a fine volcanoclastic provenance. The relict texture of the sample indicates that it is a coarse grained lithic feldspathic sandstone, with a mixed fine grained sedimentary and volcanic provenance.

b) Alteration and structure: The rock has undergone moderate alteration and weak deformation perhaps as a result of very low grade metamorphism. Plagioclase grains are partly albitised and also altered to sericite and carbonate. Volcanic lithic grains commonly show some alteration to chlorite, albite and carbonate, with trace leucoxene, but some aphanitic volcanic grains are strongly replaced by chlorite \pm carbonate. Sedimentary lithic grains and matrix are now composed mostly of quartz, sericite, with some albite, chlorite, carbonate and traces of carbonaceous material and pyrite. The alteration assemblage is of propylitic type. Deformation effects have led to a weak foliation occurring in places, defined by preferred orientation of chloritised volcanic lithic grains and by incipient formation of thin carbonaceous stylolites in-between detrital grains.

c) Mineragraphy and paragenesis: The rock contains a few grains of disseminated pyrite as part of the alteration assemblage. Largest grains are up to 0.1 mm across.

Mineral Mode: Approximate modal proportions are: plagioclase (including albite) 50%, quartz 15%, chlorite 14%, sericite (+ muscovite) and carbonate each 10% and traces of carbonaceous material, pyrite, leucoxene and K-feldspar (microcline).

Interpretation and Comments: It is interpreted that the sample represents a coarse grained lithic-feldspathic sandstone, with a mixed provenance of sedimentary and volcanic material. Lithic grains are dominated by massive to weakly foliated shale-siltstone (locally carbonaceous) and intermediate to mafic volcanic material, but with minor quartz-rich metasedimentary material (e.g. quartzite, metachert) and felsic pumiceous material. There are abundant detrital plagioclase grains, with minor quartz and altered ferromagnesian material. There is a minor shale-siltstone matrix component. The rock has undergone moderate alteration, perhaps as the result of very low grade metamorphism, with the partial replacement of lithic and mineral grains, and the matrix, by chlorite, carbonate, sericite and albite. In places, a weak foliation occurs, defined by preferred orientation of chloritised volcanic grains and by incipient carbonaceous stylolites.

378112 TS

Summary: Coarse grained lithic-feldspar-quartz sandstone, with abundant lithic clasts dominated by altered volcanic material, but with a smaller population of fine grained sedimentary material. There are also abundant individual mineral grains, dominated by plagioclase and quartz, and a small matrix component. The rock has under pervasive, moderate to strong propylitic alteration, perhaps caused by very low grade metamorphism, with replacement by chlorite, carbonate, albite, sericite, a little leucoxene/rutile and trace pyrite.

Handspecimen: The sample is composed of a massive, coarse grained lithic-feldspar-quartz sandstone. It contains prominent angular detrital lithic clasts up to 8 mm across, some of which are evidently dark grey carbonaceous fine grained sedimentary material and other porphyritic volcanic material. There are also abundant detrital plagioclase grains up to 4 mm across and less abundant quartz, all set in a finer grained grey matrix. The rock may have undergone pervasive alteration to chlorite, sericite and carbonate, with testing of the section offcut with dilute HCl showing a mild reaction, suggestive that the carbonate is dolomite, or that only minor calcite is present. Staining of the section offcut with sodium cobaltinitrite indicated that there are a few detrital grains of K-feldspar. The rock is very weakly magnetic, with susceptibility up to 25×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict medium to coarse grained relict detrital grain texture is well preserved. The rock contains abundant, mostly angular lithic clasts up to 8 mm across and individual mineral grains. These are rather tightly packed, but there is a minor matrix component. Lithic grains are dominated by former volcanic material, including some that is pumiceous and some that is porphyritic (plagioclase phenocrysts in a fine grained groundmass). It is speculated that the volcanic material is of intermediate to felsic composition. The rock contains a smaller population of fine grained sedimentary/metasedimentary lithic grains. These include massive to foliated carbonaceous shale/siltstone, quartzite and recrystallised chert. Individual mineral grains are dominated by detrital, angular plagioclase up to 4 mm across. There is also abundant quartz up to 1 mm across and a few grains of K-feldspar, muscovite and trace FeTi oxide, biotite, rutile, zircon and tourmaline. The matrix may have been silty to muddy but is now altered and recrystallised. The relict texture and detrital grain composition indicates that the rock is a lithic-feldspar-quartz sandstone, with a dominantly volcanic provenance, but some detritus has evidently come from a fine grained sedimentary and siliceous metamorphic source.

b) Alteration and structure: The clastic sedimentary rock has undergone moderate to strong and pervasive alteration. Volcanic lithic clasts have been replaced by assemblages that include chlorite, carbonate, albite, minor sericite and trace leucoxene/rutile and pyrite. Detrital plagioclase grains are mostly albitised and also replaced by carbonate, sericite and chlorite. K-feldspar is also slightly altered to sericite and carbonate, with FeTi oxide being mostly replaced by leucoxene/rutile. The fine grained matrix material has been altered and replaced by chlorite and carbonate, with trace pyrite. The alteration assemblage is of propylitic type and may be due to very low grade metamorphism.

c) Mineragraphy and paragenesis: The rock contains a little disseminated pyrite as part of the alteration assemblage. Largest grains are up to 0.3 mm across.

Mineral Mode: Approximate modal proportions are: plagioclase (mostly albite) 50%, quartz and carbonate each 15%, chlorite 12%, K-feldspar and sericite + muscovite each 3%, leucoxene/rutile 1% and traces of carbonaceous material, FeTi oxide, pyrite, biotite, tourmaline and zircon.

Interpretation and Comments: It is interpreted that the sample represents a coarse grained lithic-feldspar-quartz sandstone, with abundant lithic clasts dominated by altered volcanic

material, but with a smaller population of fine grained sedimentary material. There are also abundant individual mineral grains, dominated by plagioclase and quartz, and a small matrix component. The rock has under pervasive, moderate to strong propylitic alteration, perhaps caused by very low grade metamorphism, with replacement by chlorite, carbonate, albite, sericite, a little leucoxene/rutile and trace pyrite.

378113 TS

Summary: Medium to coarse grained lithic sandstone, with minor detrital quartz and plagioclase grains. The lithic grains are dominated by fine grained sedimentary material (shale, siltstone, siliceous argillite, chert/jasper, quartzite) and intermediate to mafic igneous material (?andesite/basalt, dolerite). There is only a minor matrix component. The rock has undergone strong propylitic alteration and replacement by chlorite, with subordinate albite, quartz and minor sericite. There are also a couple of thin quartz veins. A little pyrite might have formed as part of the alteration assemblage but was later replaced by goethite as a result of weathering.

Handspecimen: The sample is composed of a relatively massive, slightly weathered, pale green-brown-grey medium to coarse grained sandstone. It contains abundant lithic detrital grains up to 3 mm across, some of which may be of fine grained volcanic derivation and others of fine grained sedimentary derivation. There are also several small reddish jasper grains, along with a few quartz grains. The rock may have undergone chlorite alteration and shows slight goethite staining in places, as a result of weathering. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The rock contains a little disseminated magnetite as it is moderately magnetic, with susceptibility up to 920×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is moderately well preserved. The rock contains tightly packed angular to sub-rounded detrital grains up to 2.5 mm across, with only a small matrix component. Detrital grains are dominated by lithics, with many being of fine grained sedimentary derivation, including sericitic and chloritic shale and siltstone, siliceous argillite (rarely with radiolarians) grading into chert and jasper, and rare quartzite. There are also relatively abundant intermediate to mafic igneous clasts; relict textures suggest possible lava (e.g. andesite/basalt) as well as medium grained dolerite. The rock contains a minor component of detrital grains of quartz, altered plagioclase and FeTi oxide (e.g. titanomagnetite). The minor matrix component may have been silty to muddy, but is now totally altered. From the relict textures, the rock is interpreted to be a medium to coarse grained lithic sandstone, with a mixed fine grained sedimentary and intermediate to mafic igneous provenance.

b) Alteration and structure: The has sustained strong alteration and minor veining, with subsequent weathering effects imposed. Igneous lithic clasts have been replaced by albite, chlorite and minor sericite. Fine grained sedimentary clasts are dominated by quartz, but some have appreciable chlorite, sericite and traces of hematite. The altered matrix is dominantly chloritic. Detrital grains of FeTi oxide are partly altered to hematite and leucoxene. The rock has been cut by a couple of anastomosing quartz veins up to 0.4 mm wide. The alteration assemblage is considered to be of propylitic type and has been later affected by slight weathering. This is manifest by patchy goethite staining and many small goethite aggregates, some of which may be pseudomorphs after former alteration-derived pyrite. Some of the alteration-derived chlorite has been degraded to khaki-coloured nontronite.

c) Mineragraphy and paragenesis: There are no sulphides in the sample, but it could have contained a little disseminated pyrite as apart of the alteration assemblage. However, all pyrite was later replaced by goethite as a result of weathering.

Mineral Mode: Approximate modal proportions are: chlorite/nontronite 40%, quartz 35%, plagioclase (albite) 17%, sericite 4%, goethite 2%, hematite and FeTi oxide (titanomagnetite) each 1% and a trace of leucoxene.

Interpretation and Comments: It is interpreted that the sample is an altered medium to coarse grained lithic sandstone, with minor detrital quartz and plagioclase grains. The lithic grains

are dominated by fine grained sedimentary material (shale, siltstone, siliceous argillite, chert/jasper, quartzite) and intermediate to mafic igneous material (?andesite/basalt, dolerite). There is only a minor matrix component. There has been strong propylitic alteration and replacement by chlorite, with subordinate albite, quartz and minor sericite. There are also a couple of thin quartz veins. A little pyrite might have formed as part of the alteration assemblage but was later replaced by goethite as a result of weathering.

378114 TS

Summary: Retrogressively altered fine to medium grained mafic igneous rock, perhaps originally a quartz dolerite. Although the rock contains relict clinopyroxene, it is possible that this phase represents a metamorphic product replacing earlier igneous clinopyroxene. The original igneous rock contained considerable plagioclase, with interstitial K-feldspar and quartz and a little disseminated FeTi oxide. The rock could have been metamorphosed, leading to recrystallisation of clinopyroxene, but was then retrogressively altered, with replacement by abundant chlorite, albite, epidote and minor carbonate, pyrite and leucoxene. The rock has been cut by a few thin sheared zones, along which development of chlorite, epidote and carbonate is prevalent.

Handspecimen: The sample is composed of a massive, dark green-grey fine to medium grained altered mafic igneous rock. It was probably rich in plagioclase and ferromagnesian material but has evidently been partly replaced by chlorite, with a few pyrite aggregates up to 3 mm across. Staining of the section offcut with sodium cobaltinitrite indicated that there is a moderate amount of interstitial K-feldspar. The rock is weakly magnetic, with susceptibility up to 65×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict fine to medium grained igneous texture is moderately preserved. The rock retains considerable relict inequigranular clinopyroxene, in grains up to 0.3 mm across and commonly forming aggregates. Clinopyroxene is intergrown with altered plagioclase laths up to 0.5 mm long, as well as interstitial K-feldspar, quartz (aggregates up to 1 mm across) and a little disseminated FeTi oxide. Small acicular relict grains of apatite occur in the interstitial patches of plagioclase-K-feldspar-quartz. The relict texture and inferred primary mineralogy could imply that the rock represents a type of quartz dolerite (albeit containing significant late magmatic K-feldspar – maybe it could be termed a “monzodolerite”). However, the relict texture of clinopyroxene is unusual. The granular nature of clinopyroxene is atypical of igneous clinopyroxene and it might indicate that the mafic igneous rock underwent some form of metamorphic recrystallisation prior to subsequent retrograde alteration.

b) Alteration and structure: The mafic igneous rock (or metamorphosed mafic igneous rock) has undergone strong retrograde alteration of propylitic type. There has been complete replacement of all plagioclase by albite and it and some of the K-feldspar have also been further replaced by fine grained chlorite, with aggregates of fine grained epidote and a little carbonate. Clinopyroxene is weakly replaced by chlorite and epidote, with possible development of a little actinolite. Most igneous FeTi oxide has been replaced by leucoxene and the rock contains a few isolated grains and aggregates of pyrite up to 1 mm across as part of the alteration assemblage. In places, the sample exhibits stronger replacement patches up to several millimetres across dominated by chlorite, but with a little epidote. There have been a few thin zones of shearing imposed, along which there is chlorite development, accompanied by minor epidote and patches of carbonate.

c) Mineragraphy and paragenesis: The rock contains a little disseminated pyrite, forming aggregates up to 1 mm across, as part of the retrograde alteration assemblage.

Mineral Mode: Approximate modal proportions are: clinopyroxene 30%, chlorite 25%, plagioclase (albite) 20%, K-feldspar 10%, quartz 7%, epidote 5%, carbonate 2%, leucoxene and pyrite each 1% and traces of apatite, FeTi oxide and ?actinolite.

Interpretation and Comments: It is interpreted that the sample represents a former fine to medium grained mafic igneous rock, perhaps a K-feldspar-bearing quartz dolerite. Although the rock contains relict clinopyroxene, it is possible that this phase represents a metamorphic product replacing earlier igneous clinopyroxene. The original igneous rock contained considerable plagioclase, with interstitial K-feldspar and quartz and a little disseminated FeTi

oxide. The rock could have been metamorphosed, leading to recrystallisation of clinopyroxene, but was then retrogressively altered to a propylitic assemblage, with replacement by abundant chlorite, albite, epidote and minor carbonate, pyrite and leucoxene. The rock has been cut by a few thin sheared zones, along which development of chlorite, epidote and carbonate is prevalent.

378115 TS

Summary: Coarse grained lithic-crystal felsic tuff, composed mainly of pumiceous and flow-foliated and porphyritic felsic volcanic fragments and individual volcanic quartz grains (former phenocrysts) set in a fine to medium grained pumiceous matrix. There is no textural evidence for sedimentary re-working of the pyroclastic rock. There has been strong and pervasive alteration of transitional phyllic-propylitic type that has caused replacement of all volcanic lithic material and uncommon feldspar, ferromagnesian and FeTi oxide grains. The alteration assemblage is dominated by fine grained sericite and quartz, with minor chlorite and a little leucoxene.

Handspecimen: The sample is composed of a rather massive, coarse grained lithic-crystal tuff. It contains scattered irregular shaped dark green fragments of fine grained volcanic material (perhaps pumice fragments originally), plus scattered quartz grains (up to 3 mm across) and a few sericitised feldspar grains in a finer grained altered clastic matrix, probably with significant development of sericite and chlorite. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The rock is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict texture is moderately well preserved. It is evident that the rock is a medium to very coarse grained lithic-crystal felsic tuff (i.e. a pyroclastic rock). It has pseudomorphs after abundant highly angular and irregular lithic fragments up to 8 mm across, plus abundant discrete volcanic quartz grains (originally phenocrysts) up to 2.5 mm across. There are also a few altered feldspar and ferromagnesian phenocrysts (the latter possibly having been biotite) and scattered microphenocrysts of FeTi oxide (now altered). Most lithic grains were composed of fine grained flow foliated felsic volcanic material, some of which is porphyritic (relict quartz phenocrysts and rare altered ferromagnesian grains FeTi oxide and zircon) and some which retains relict pumice textures. There are one or two lithic fragments that are non-volcanic; these are composed of fine grained quartzite and might represent small fragments of siliceous basement material. The lithic fragments and discrete mineral grains occur in an altered and recrystallised matrix that appears to have been largely composed of fine to medium grained pumiceous material. The sample shows no textural evidence for sedimentary transport and there is preservation of delicate pumice textures, i.e. the rock is unlikely to represent an epiclastic sandstone.

b) Alteration and structure: The rock has undergone strong pervasive alteration maybe due to very low grade metamorphism and/or hydrothermal processes. All volcanic lithic fragments and matrix material have been totally replaced (except for relict quartz phenocrysts and zircon grains), with the main assemblage being fine grained sericite and minor chlorite plus trace leucoxene/rutile. However, altered matrix material also contains considerable fine grained quartz. Former feldspar grains have been replaced by sericite, ferromagnesian grains by sericite + leucoxene/rutile and FeTi oxide by leucoxene/rutile. In the matrix, there are also a few small quartz-rich aggregates that may be due to alteration. The mineral assemblage is consistent with the alteration being of transitional phyllic-propylitic type.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: quartz 50%, sericite 40%, chlorite 9%, leucoxene/rutile 1% and a trace of zircon.

Interpretation and Comments: It is interpreted that the sample is a coarse grained lithic-crystal felsic tuff, composed mainly of pumiceous and flow-foliated and porphyritic felsic volcanic fragments and individual volcanic quartz grains (former phenocrysts) set in a fine to medium grained pumiceous matrix. There has been strong and pervasive alteration of transitional phyllic-propylitic type that has caused replacement of all volcanic lithic material and uncommon feldspar, ferromagnesian and FeTi oxide grains. The alteration assemblage is

dominated by fine grained sericite and quartz, with minor chlorite and a little leucoxene. There is no textural evidence for sedimentary re-working of the pyroclastic rock.

378116 TS

Summary: Medium to coarse grained lithic tuff, dominated by former pumiceous fragments. It is possible that the rock represents an altered felsic to intermediate volcanic composition. The rock may have also contained a few feldspar grains and small grains of FeTi oxide. Very strong phyllic alteration, perhaps caused by hydrothermal processes, has overprinted the original pyroclastic material, partially destroying relict texture and causing total replacement by fine grained sericite and quartz, with scattered porphyroblastic grains of carbonate, a little leucoxene and hematite, and a trace of pyrite.

Handspecimen: The sample is composed of a strongly altered, pale grey-green coloured, medium to coarse grained fragmental rock, perhaps representing a pyroclastic of intermediate to felsic composition. There are outlines of fine grained volcanic fragments up to 5-6 mm across and possible pseudomorphs after former feldspar grains. The rock appears to have been largely replaced by fine grained sericite, maybe with minor quartz, chlorite, carbonate and hematite. In places, there is a weak foliation, defined by preferred orientation of sericitic aggregates. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The rock is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict fragmental texture is moderately preserved. The rock is very strongly altered, but there are outlines after former irregular, angular to elongated pumiceous fragments up to 5 mm across. Many of these preserve relict elongate bubble cavities and flow foliation. There are also a few possible pseudomorphs after small tabular feldspar grains up to 1 mm across as well as scattered altered FeTi oxide grains up to 0.6 mm across. Pumiceous fragments appear to be rather tightly packed, but there may be a small matrix component of finer pumiceous material. The relict texture is tentatively interpreted as indicating that the original rock was a lithic (pumiceous) tuff, probably of intermediate to felsic volcanic composition.

b) Alteration and structure: The rock has been very strongly altered and no primary igneous minerals are recognised. This may be due to hydrothermal alteration. Pumiceous material has been totally replaced by fine grained aggregates that range from sericite-rich to quartz-rich, with scattered carbonate porphyroblasts up to 0.5 mm across and traces of fine grained leucoxene, hematite and pyrite. Former feldspar grains have been replaced by sericite and FeTi oxide grains by leucoxene and/or hematite. In places, a weak foliation is apparent, defined by preferred orientation of alteration-derived sericite. The alteration is considered to be a variant of phyllic type.

c) Mineragraphy and paragenesis: The sample contains rare grains of pyrite up to 0.3 mm across as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: sericite 60%, quartz 32%, carbonate 6%, leucoxene and hematite each 1% and a trace of pyrite.

Interpretation and Comments: It is interpreted that the sample may represent a very strongly altered medium to coarse grained lithic tuff, dominated by former pumiceous fragments. The original pyroclastic rock could have been of felsic to intermediate volcanic composition. It may have also contained a few feldspar grains and small grains of FeTi oxide. Very strong phyllic alteration, perhaps caused by hydrothermal processes, has overprinted the original pyroclastic material, partially destroying relict texture and causing total replacement by fine grained sericite and quartz, with scattered porphyroblastic grains of carbonate, a little leucoxene and hematite, and a trace of pyrite.

378118 TS

Summary: Medium grained quartz-lithic-feldspathic sandstone, with abundant angular to sub-rounded detrital grains of quartz and lithic, with minor plagioclase and a little muscovite, traces of biotite, K-feldspar, tourmaline, zircon, leucoxene and chromite. Most lithic grains are composed of fine grained shaly material, with local grains being pigmented by carbonaceous material. Other lithic grains are cherty or quartzitic and rare grains contain fuchsite, which, along with the trace grains of chromite, indicate a minor ultramafic source for detritus. The rock has developed substantial amounts of carbonate, along with minor sericite, in the matrix, perhaps due to very low grade metamorphism.

Handspecimen: The sample is composed of a relatively massive, medium grained, pale brownish-grey sandstone, probably containing abundant quartz, feldspar and lithic grains up to 1 mm across, along with a few small muscovite flakes. There may be considerable fine grained carbonate and sericite in the matrix. Testing of the section offcut with sodium cobaltinitrite did not indicate the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is moderately well preserved. The rock is a medium grained sandstone, with abundant quartz, lithic and feldspar detrital grains, mostly <0.5 mm across, but locally up to 1-1.5 mm across. Detrital grains are angular to sub-rounded and are enclosed in an altered recrystallised matrix. The most abundant detrital grain type is quartz. There are also abundant fine grained sedimentary lithic grains, e.g. fine grained sericitic shale (locally pigmented by dark carbonaceous material), grading into siliceous argillite and finely recrystallised chert. There are a few fine grained quartzite grains along with rare grains containing significant green fuchsite (altered ultramafic protolith). There are scattered detrital plagioclase grains, along with a few detrital muscovite flakes and traces of biotite, K-feldspar, tourmaline, zircon, chromite and leucoxene. Detrital grains are relatively tightly packed, but there is a subordinate matrix component that is altered and recrystallised, being dominated by carbonate and containing minor sericite and quartz. From the relict texture and grain compositions, the rock is interpreted to be a quartz-lithic (-plagioclase) sandstone. Its provenance is dominated by fine grained sedimentary material, but it is likely that there is a felsic igneous (plutonic) provenance and a minor component of ultramafic material (giving rise to chromite and fuchsite-bearing lithics).

b) Alteration and structure: The rock has undergone moderate alteration, manifest largely in the replacement of matrix material by fine to medium grained carbonate, plus minor sericite and quartz. Detrital plagioclase grains are partly altered to albite and sericite and there is a trace of fine grained pyrite in the matrix.

c) Mineragraphy and paragenesis: The sample contains a trace of fine grained pyrite as part of the alteration assemblage in the groundmass. There are rare detrital grains of chromite, indicative of a small ultramafic component in the provenance of detrital grains.

Mineral Mode: Approximate modal proportions are: quartz 55%, carbonate 25%, sericite + muscovite 10%, plagioclase (including albite) 8% and traces of carbonaceous material, pyrite, K-feldspar, fuchsite, tourmaline, chromite, biotite, zircon and leucoxene.

Interpretation and Comments: It is interpreted that the sample is a medium grained quartz-lithic-feldspathic sandstone, with abundant angular to sub-rounded detrital grains of quartz and lithic, with minor plagioclase and a little muscovite, traces of biotite, K-feldspar, tourmaline, zircon, leucoxene and chromite. Most lithic grains are composed of fine grained shaly material, with local grains being pigmented by carbonaceous material. Other lithic grains are cherty or quartzitic and rare grains contain fuchsite, which, along with the trace grains of chromite, indicate a minor ultramafic source for detritus, although most detrital

grains are of fine grained sedimentary and perhaps plutonic felsic igneous origin. The rock has developed substantial amounts of carbonate, along with minor sericite, in the matrix, perhaps due to very low grade metamorphism.

378119 TS

Summary: Altered porphyritic, slightly amygdaloidal dacite, originally containing scattered phenocrysts of plagioclase and ferromagnesian material (mostly pyroxene), plus microphenocrysts of FeTi oxide and quartz in a fine grained feldspathic groundmass. The rock has undergone low grade alteration of propylitic type that has caused development of a replacement assemblage of albite, with subordinate sericite and chlorite, with minor carbonate, quartz and leucoxene/rutile. Amygdules are filled by one or more of quartz, carbonate, sericite and chlorite.

Handspecimen: The sample is composed of a massive, fine to medium grained, porphyritic and locally amygdaloidal felsic to intermediate igneous rock. It contains altered phenocrysts of plagioclase and dark ferromagnesian material up to 4 mm across in a fine to medium grained green-grey feldspathic groundmass. A few spheroidal to irregular amygdules up to 4 mm across are present and appear to be mostly filled by carbonate. Pervasive alteration has affected the rock, with development of chlorite, sericite and carbonate. Testing of the section offcut with sodium cobaltinitrite did not indicate the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $\sim 20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. The rock contains tabular to blocky altered phenocrysts of plagioclase up to 4 mm across and less common altered phenocrysts of ferromagnesian material up to 2 mm across, plus a few microphenocrysts of quartz and altered FeTi oxide. There are also a few glomeroporphyritic aggregates up to 3 mm across that were dominated by grains of ferromagnesian material \pm plagioclase \pm FeTi oxide \pm apatite. The ferromagnesian phase in the rock was probably pyroxene, judging by relict grain shape, although it is possible that a few grains of biotite were also present. The phenocrystal phases occur in an altered and recrystallised groundmass, probably originally fine grained (?aphanitic) that was dominated by feldspar, along with minor quartz, ferromagnesian material and traces of FeTi oxide and apatite. A few spheroidal to irregular amygdules up to 2.5 mm across are present in the groundmass. The relict texture and interpreted primary minerals imply that the rock represents a porphyritic and slightly amygdaloidal dacite. It could represent a lava or shallow, sub-volcanic intrusive.

b) Alteration and structure: The rock has undergone strong pervasive alteration. All plagioclase phenocrysts have been albitised and further replaced by fine grained sericite and minor carbonate. All ferromagnesian material has been replaced by fine grained chlorite \pm sericite \pm leucoxene/rutile, although a few grains have been replaced by carbonate. Igneous FeTi oxide has been replaced by leucoxene/rutile \pm chlorite. The groundmass has been largely recrystallised and replaced. It is now dominated by inequigranular fine to medium grained albite, with a few patches of quartz and minor fine grained carbonate, chlorite and sericite, with traces of leucoxene and pyrite. Amygdules have been filled by fine to medium grained aggregates containing one or more of the phases quartz, carbonate, sericite and chlorite. Slight weathering effects imposed on the rock are manifest by local patchy aggregates of fine grained goethite/hematite and by staining of chloritised ferromagnesian sites by goethite. Alteration in the rock is of propylitic type and could be due to very low grade metamorphism.

c) Mineralogy and paragenesis: The sample contains a trace of fine grained pyrite as part of the alteration assemblage in the groundmass.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 60%, sericite 12%, quartz and chlorite each 10%, carbonate 6%, rutile/leucoxene and goethite/hematite each 1% and traces of apatite and pyrite.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic, slightly amygdaloidal dacite, perhaps representing a lava or shallow intrusive. It originally contained scattered phenocrysts of plagioclase and ferromagnesian material (mostly pyroxene), plus microphenocrysts of FeTi oxide and quartz in a fine grained feldspathic groundmass. The rock has undergone low grade alteration of propylitic type that has caused development of a replacement assemblage of albite, with subordinate sericite and chlorite, with minor carbonate, quartz and leucoxene/rutile. Amygdules are filled by one or more of quartz, carbonate, sericite and chlorite.

378120 TS

Summary: Altered medium to coarse grained lithic-feldspathic-quartz sandstone, exhibiting a strong volcanic provenance, with intermediate to felsic volcanic detritus. Lithic grains are dominated by altered porphyritic, fine grained (aphanitic) intermediate volcanic material and feldspar grains are dominated by altered plagioclase. A subordinate amount of fine grained partly recrystallised matrix material is present, with dominant albite and minor K-feldspar, quartz and chlorite. The rock has undergone low grade alteration of propylitic type, probably as a result of incipient metamorphism. Albite and chlorite are the main alteration minerals, with a little sericite. A trace of pyrite may have developed as part of the alteration assemblage, but most has subsequently been replaced by goethite as a result of supergene oxidation.

Handspecimen: The sample is composed of a massive, fine to medium grained, medium to coarse grained pale green-grey altered volcanoclastic sandstone or tuff. It contains altered lithic fragments up to 6 mm across and abundant finer grained feldspar and quartz. Pervasive alteration may have caused development of chlorite, especially at lithic grain sites, as well as minor sericite and a trace of pyrite. Slight weathering effects have led to local goethite stained voids, perhaps after former pyrite grains. Testing of the section offcut with sodium cobaltinitrite showed that minor K-feldspar is present. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict texture is moderately well preserved. The rock has a clastic, inequigranular texture, with abundant angular detrital grains of plagioclase and subordinate quartz, mostly <1 mm across. There are also scattered larger (up to 4 mm) altered lithic grains and a little detrital muscovite and biotite (most of the latter is altered) and trace FeTi oxide (completely altered). Lithic grains preserve a porphyritic volcanic texture, with altered plagioclase phenocrysts set in an altered fine grained (aphanitic) groundmass. It is speculated that the lithic grains are of former andesitic composition. The detrital grains are relatively tightly packed, but there is a subordinate amount of fine grained matrix component, dominated by fine grained recrystallised feldspars and quartz. From the relict texture and interpreted primary components, the rock is considered to represent a lithic-feldspathic-quartz sandstone, clearly of volcanic provenance and with intermediate to felsic volcanic composition.

b) Alteration and structure: The rock has undergone moderate to strong pervasive propylitic alteration, probably due to very low grade metamorphism. All original plagioclase has been replaced by albite, with a little sericite and chlorite. Volcanogenic lithic fragments have been largely replaced by fine grained chlorite, with albite having replaced plagioclase. The traces of detrital biotite have been partly replaced by chlorite and FeTi oxide altered to titanite/leucoxene. The matrix material has been replaced by fine grained inequigranular albite, with minor K-feldspar, quartz and chlorite. There may have been a trace of pyrite formed during alteration, but most has been subsequently altered to goethite as a result of supergene oxidation.

c) Mineragraphy and paragenesis: The sample contains a trace of fine grained pyrite as part of the alteration assemblage, but most pyrite has subsequently been replaced by goethite.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 70%, quartz 15%, chlorite 10%, K-feldspar 3%, sericite/muscovite 1% and traces of biotite, pyrite, goethite and leucoxene/titanite.

Interpretation and Comments: It is interpreted that the sample is a very low grade metamorphosed lithic-feldspathic-quartz sandstone of intermediate to felsic volcanic provenance. It contains scattered larger lithic grains and smaller altered plagioclase and quartz grains. There has been pervasive propylitic alteration, developing an assemblage

dominated by albite and chlorite, with minor K-feldspar and sericite. Tiny traces of pyrite formed during alteration but most have been replaced by goethite as a result of supergene oxidation.

378121 TS

Summary: Altered fine grained porphyritic felsic volcanic rock, possibly representing a former lava. The rock contained scattered feldspar phenocrysts and possible microphenocrysts of ferromagnesian material and FeTi oxide in a fine grained quartzofeldspathic groundmass. There has been very strong pervasive alteration, likely to be caused by hydrothermal action. This has resulted in the replacement of the igneous rock by a phyllic assemblage of quartz and sericite-illite, with traces of rutile and hematite.

Handspecimen: The sample is composed of a grey-pink, altered porphyritic fine grained igneous rock, probably of rather felsic composition. It contained scattered feldspar phenocrysts up to 3 mm across, but these have apparently been altered and replaced by sericite. The groundmass is fine grained and is likely to have been quartzofeldspathic in composition. It is probably slightly pigmented by hematite. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, it is evident that the rock is strongly and pervasively altered, but it has moderate retention of relict porphyritic texture. There are pseudomorphs after former tabular feldspar phenocrysts up to 2.5 mm long and possible pseudomorphs after a few microphenocrysts of former ferromagnesian material and FeTi oxide. Former feldspar phenocrysts contain rare small relict zircon inclusions. The original groundmass of the rock may have been fine grained/aphanitic and maybe of quartzofeldspathic composition, but it has been totally altered and recrystallised. It is interpreted from the relict texture and possible primary mineralogy that the original rock was a porphyritic fine grained felsic igneous type, maybe representing a former lava.

b) Alteration and structure: The rock has sustained strong and pervasive alteration, considered likely to be the result of hydrothermal processes. All feldspar phenocrysts have been replaced by fine grained aggregates of sericite/illite. Ferromagnesian grains have been replaced by sericite/illite and a little rutile and hematite, with FeTi oxide having been replaced by rutile \pm hematite. The groundmass has been totally replaced by an inequigranular, fine to medium grained (up to 0.4 mm) mass rich in quartz, with subordinate amounts of fine grained sericite/illite and traces of rutile and hematite. The groundmass also contains a few alteration patches up to 2 mm across of sericite/illite into which fine to medium grained crystalline quartz projects. The alteration assemblage is interpreted to be of phyllic type. Slight weathering effects are manifest in the rock by the formation of scattered tiny goethite aggregates throughout.

c) Mineragraphy and paragenesis: No sulphide minerals have been observed in the sample.

Mineral Mode: Approximate modal proportions are: quartz 70%, sericite/illite 29% and traces of zircon, rutile, hematite and goethite.

Interpretation and Comments: It is interpreted that the sample represents a former fine grained porphyritic felsic volcanic rock, possibly representing a lava. The rock contained scattered feldspar phenocrysts and possible microphenocrysts of ferromagnesian material and FeTi oxide in a fine grained quartzofeldspathic groundmass. There has been very strong pervasive phyllic alteration, likely to be caused by hydrothermal action. This has resulted in the replacement of the igneous phases by quartz and sericite-illite, with traces of rutile and hematite.

378125 TS

Summary: Altered mildly porphyritic and amygdaloidal fine grained felsic igneous rock, probably of dacitic to rhyolitic composition and maybe representing a lava. The original rock contained scattered phenocrysts of plagioclase and rare ferromagnesian material in a fine grained quartzofeldspathic groundmass containing scattered vesicles. The rock has undergone strong pervasive alteration of transitional phyllic-propylitic type, with replacement by albite and subordinate quartz and sericite, with a little K-feldspar. Vesicles were filled by quartz and sericite, forming amygdules.

Handspecimen: The sample is composed of a massive, fine grained, felsic igneous rock. It contains scattered altered feldspar phenocrysts up to 4 mm across and fine grained aggregates of yellow-green-grey sericite \pm quartz up to 4 mm across that might represent amygdules, in a pale pink quartzofeldspathic groundmass. Feldspar phenocrysts appear to be partly sericitised. Testing of the section offcut with sodium cobaltinitrite showed that minor K-feldspar is present in the groundmass. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic and amygdular texture is moderately well preserved. The rock is relatively sparsely porphyritic, with scattered altered tabular plagioclase phenocrysts up to 3 mm across and rare pseudomorphs after a prismatic ferromagnesian phase up to 2.5 mm long. The latter could represent former hornblende or pyroxene. The rock also contained a few microphenocrysts of FeTi oxide, now totally altered. The phenocrystal phases were set in a fine grained, holocrystalline groundmass composed of dominant fine grained feldspar (in places with sub-trachytic texture), with minor quartz and possible ferromagnesian material. In the groundmass, there are scattered amygdules, representing the sites of original vesicles. The amygdules are irregular to spheroidal in shape and up to 3 mm across. The relict texture and implied primary mineralogy of the rock suggests that it is a porphyritic and amygdular felsic volcanic, e.g. a lava of dacitic to rhyolitic composition.

b) Alteration and structure: The rock has undergone strong pervasive alteration, probably due to very low grade metamorphism and/or hydrothermal effects. Plagioclase phenocrysts have been replaced by albite, commonly with abundant fine grained sericite. Former ferromagnesian grains have been replaced by sericite and a trace of leucoxene, and FeTi oxide has been replaced by leucoxene. The groundmass has been replaced by dominant fine to medium grained albite, with subordinate amounts of quartz and sericite, a little K-feldspar and traces of leucoxene. Amygdules are filled by one or both of medium grained quartz or fine grained sericite. A single discontinuous vein up to 0.2 mm wide of quartz and sericite was noted. The alteration is dominated by albite-sericite-quartz and is considered to be of transitional phyllic-propylitic type. The rock has sustained slight weathering effects, leading to a little goethite staining.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 60%, quartz 20%, sericite 17%, K-feldspar 2% and traces of leucoxene and goethite.

Interpretation and Comments: It is interpreted that the sample represents a former porphyritic and amygdular felsic volcanic rock, e.g. lava, of dacitic to rhyolitic composition. It originally contained scattered phenocrysts of plagioclase and rare ferromagnesian material in a fine grained feldspar-rich groundmass containing scattered small amygdules. There has been pervasive alteration of transitional phyllic-propylitic type, perhaps as a result of low grade metamorphism and/or hydrothermal processes, to develop an assemblage rich in albite, with subordinate quartz and sericite and a little K-feldspar. Amygdules are filled by quartz and sericite.

378126 TS

Summary: Altered porphyritic quartz latite or rhyodacite, possibly representing a shallow intrusive or lava. The rock contained scattered phenocrysts of plagioclase, hornblende and possibly pyroxene in a fine grained holocrystalline groundmass dominated by K-feldspar, plagioclase and quartz. The rock has undergone pervasive strong alteration, with replacement of plagioclase by albite and development of biotite, chlorite and sericite/muscovite, mainly from replacement of the ferromagnesian phases. In the groundmass, there has been development of a few metasomatic patches of quartz, biotite and muscovite.

Handspecimen: The sample is composed of a relatively massive, porphyritic, fine grained intermediate to felsic igneous rock. It contains scattered altered feldspar phenocryst and elongate altered ferromagnesian phenocrysts (possibly hornblende originally) up to a few millimetres in length. The phenocrysts occur in a pink-red feldspathic groundmass. Testing of the section offcut with sodium cobaltinitrite showed that abundant K-feldspar is present in the groundmass. Ferromagnesian phenocrysts may have been replaced by chlorite. The sample is moderately magnetic, with susceptibility up to 200×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. The rock contains scattered altered tabular plagioclase phenocrysts up to 3.5 mm across and altered prismatic ferromagnesian phenocrysts up to 3 mm long. From the relict shapes of the latter, it is interpreted that they represent former hornblende grains. The rock also contains a few pseudomorphs after microphenocrysts of another ferromagnesian phase, possibly pyroxene, up to 0.6 mm across. There are a few glomeroporphyritic aggregates up to several millimetres across consisting of altered plagioclase and ferromagnesian phases. These, and the phenocrysts, are set in a fine grained, holocrystalline groundmass, dominated by K-feldspar and plagioclase, with subordinate quartz, a little altered ferromagnesian material and a trace of FeTi oxide (e.g. titanomagnetite). From the relict texture and inferred primary mineralogy, the rock is interpreted to represent a porphyritic quartz latite or rhyodacite, perhaps being a former shallow intrusive or lava.

b) Alteration and structure: The rock has undergone strong pervasive alteration, interpreted to be at least partly due to low grade metamorphism. Former plagioclase has been albitised and also flecked by sericite and a little chlorite. Former hornblende grains have been completely altered to fine grained aggregates of green-brown biotite, with a little sericite/muscovite and chlorite and trace rutile. Former ?pyroxene grains have been replaced by sericite/muscovite and trace rutile. The groundmass is slightly recrystallised and is hematite-pigmented; it also shows minor development of chlorite, biotite, sericite and trace rutile. In the groundmass, there are a few irregular ?metasomatic patches of fine to medium grained quartz \pm biotite \pm muscovite, up to 1.5 mm across. The alteration assemblage is considered to be transitional between potassic and propylitic.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There is a trace of relict igneous FeTi oxide.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 50%, K-feldspar 30%, quartz 10%, biotite 4%, sericite/muscovite 3%, chlorite 2% and traces of hematite, rutile and FeTi oxide.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic quartz latite or rhyodacite, possibly representing a shallow intrusive or lava. The rock contained scattered phenocrysts of plagioclase, hornblende and possibly pyroxene in a fine grained holocrystalline groundmass dominated by K-feldspar, plagioclase and quartz. The rock has undergone pervasive strong alteration, with replacement of plagioclase by albite and development of biotite, chlorite and sericite/muscovite, mainly from replacement of the

ferromagnesian phases. In the groundmass, there has been development of a few metasomatic patches of quartz, biotite and muscovite. The alteration assemblage is transitional between potassic and propylitic in character.

378127 TS

Summary: Sparsely porphyritic and weakly flow foliated intermediate to felsic igneous rock, perhaps representing a lava. There are pseudomorphs after a few phenocrysts of feldspar and ferromagnesian phases, plus a few altered volcanic fragments, hosted in a fine grained altered quartzofeldspathic groundmass. The rock has undergone strong oxidative alteration of phyllic type, with replacement by fine grained quartz, sericite and hematite.

Handspecimen: The sample is composed of a mauve-red to red-grey altered porphyritic intermediate to felsic igneous rock with probable relict flow banding. It is possible that the rock represents a former lava. There are a few altered feldspar phenocrysts set in an altered fine grained quartzofeldspathic groundmass. The colour of much of the sample is likely to be due to fine hematite pigmentation. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately preserved and it is possible that there are also a few altered lithic fragments. The sample displays scattered pseudomorphs after tabular feldspar phenocrysts up to 1.5 mm across as well as pseudomorphs after a few former ferromagnesian phenocrysts also up to 1.5 mm across. Relict shapes of the latter suggest that biotite and pyroxene might have been the original phases. There may be a few altered elongate fine grained lithic fragments up to several millimetres across and although relict textures are non-diagnostic, it is speculated that these possible fragments were fine grained volcanic material. The sample is composed of about 90 volume % of fine grained altered quartzofeldspathic groundmass material in which weak flow foliation could be preserved along with pseudomorphs after a few small former FeTi oxide grains. From the relict texture, the sample is interpreted to represent a lava of intermediate to felsic composition that has incorporated a few volcanic lithic fragments.

b) Alteration and structure: The original volcanic rock has been very strongly altered. There has been complete replacement of all fine grained groundmass material and possible volcanic lithic fragments by fine grained quartz, sericite and subordinate hematite. Original feldspar phenocrysts have been replaced by albite and subsequently largely replaced by sericite \pm hematite. All former ferromagnesian phenocrysts have been replaced by sericite \pm quartz \pm hematite and FeTi oxide by leucoxene. The rather abundant hematite in the alteration assemblage is not considered to be a product of contemporary weathering. Rather it may have resulted from hydrothermal or diagenetic/low grade metamorphic alteration under oxidising conditions, or reflect initially oxidising conditions during volcanic eruption. The sample displays one or two thin (<0.1 mm) veins containing quartz \pm hematite. Alteration is of phyllic type and has occurred under oxidising conditions.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There is considerable fine grained hematite as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: quartz 50%, sericite 40%, albite and hematite each 5% and a trace of leucoxene.

Interpretation and Comments: It is interpreted that the sample represents an altered sparsely porphyritic and weakly flow foliated intermediate to felsic igneous rock, perhaps emplaced as a lava. There are pseudomorphs after a few phenocrysts of feldspar and ferromagnesian phases, plus a few altered volcanic fragments, hosted in a fine grained altered quartzofeldspathic groundmass. The rock has undergone strong oxidative alteration of phyllic type, with replacement by fine grained quartz, sericite and hematite.

378128 TS

Summary: Medium to coarse grained lithic-crystal tuff of intermediate to felsic composition, but with some possibility that the rock has been reworked to form an epiclastic sandstone. There is abundant volcanic lithic material, dominated by pumiceous grains, as well as abundant altered plagioclase and minor quartz and altered ferromagnesian grains. The rock has been strongly and pervasively altered to an assemblage that is viewed as being transitional between potassic and propylitic. There has been considerable replacement by albite, K-feldspar, chlorite, carbonate and minor quartz and sericite. The altered rock contains a trace of pyrite and has been cut by rare thin carbonate veins.

Handspecimen: The sample is composed of a massive, grey, medium to coarse grained tuff or lithic-feldspathic sandstone. It contains abundant lithic grains (appear to be fine grained) up to 3-4 mm across as well as abundant feldspar grains. The rock shows slight alteration to chlorite. Testing of the section offcut with sodium cobaltinitrite showed that there is abundant K-feldspar throughout. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict texture is moderately well preserved. It is evident that the rock is a medium to coarse grained volcanoclastic, with abundant angular altered lithic grains up to 3 mm across, abundant altered plagioclase grains up to 1.5 mm across and less common altered ferromagnesian grains, quartz and a few grains of carbonate (?former limestone). Most lithic grains are of volcanic derivation although there are one or two fine grained sedimentary lithic grains, perhaps representing siliceous argillite material. Volcanic lithic grains are dominated by pumiceous material, but there are minor amounts of porphyritic volcanic grains and aphanitic to formerly glassy grains (e.g. with relict perlitic cracking). There is a small amount of fine matrix interstitial to the larger grains, perhaps representing finer pumiceous material. The relict texture of the sample implies that the rock is a medium to coarse intermediate to felsic composition lithic-crystal tuff. Although there is no strong evidence for transport and re-deposition, it is possible that the sample could represent a type of epiclastic sandstone.

b) Alteration and structure: There has been strong pervasive alteration, perhaps the result of very low grade metamorphism. The alteration is of transitional potassic-propylitic type. All volcanic lithic material has been altered, mostly to fine grained K-feldspar, albite and chlorite, with local quartz and carbonate and trace leucoxene and pyrite. Some aphanitic volcanic grains have been replaced by chlorite \pm carbonate. Plagioclase grains may have been variably albitised as well as being locally flecked by carbonate and sericite. Former ferromagnesian grains have been replaced by chlorite, carbonate and trace leucoxene. Matrix material has been replaced by fine grained K-feldspar, albite, chlorite and carbonate. The rock has been cut by uncommon, thin (<0.2 mm) anastomosing veins of carbonate. Slight supergene oxidation effects are manifest by local alteration of pyrite to goethite.

c) Mineragraphy and paragenesis: The sample contains rare grains of pyrite up to 0.1 mm across as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: plagioclase (including albite) and K-feldspar each 35%, chlorite 12% quartz and carbonate each 8%, sericite 1% and traces of leucoxene, pyrite and goethite.

Interpretation and Comments: It is interpreted that the sample is a medium to coarse grained lithic-crystal tuff of intermediate to felsic composition, but with some possibility that the rock has been reworked to form an epiclastic sandstone. It has been subjected to strong and pervasive alteration of a type transitional between potassic and propylitic. There is abundant volcanic lithic material, dominated by pumiceous grains, as well as abundant altered plagioclase and minor quartz and altered ferromagnesian grains. There has been considerable

replacement by albite, K-feldspar, chlorite, carbonate and minor quartz and sericite. The altered rock contains a trace of pyrite and has been cut by rare thin carbonate veins.

378129 TS

Summary: Altered porphyritic quartz latite, perhaps representing a former shallow intrusive or lava. The original rock contained scattered phenocrysts of plagioclase and less common phenocrysts of a ferromagnesian phase (maybe pyroxene) and microphenocrysts of FeTi oxide and quartz. There are also one or two glomeroporphyritic aggregates of plagioclase-ferromagnesian phase-FeTi oxide. Phenocrystal phases occur in a fine grained, holocrystalline groundmass dominated by K-feldspar and plagioclase, with minor quartz and ferromagnesian material. The rock has under moderate to strong and pervasive propylitic alteration, with partial replacement of the igneous minerals by albite, chlorite and a little sericite, leucoxene and titanite.

Handspecimen: The sample is composed of a massive, pink-brown altered fine grained porphyritic intermediate to felsic igneous rock. It contains scattered feldspar phenocrysts up to 3 mm across and dark green chloritised ferromagnesian phenocrysts up to 4 mm long in a fine grained hematite-pigmented feldspathic groundmass. Testing of the section offcut with sodium cobaltinitrite showed that there is abundant K-feldspar in the groundmass. The sample contains a little disseminated magnetite, as it is moderately magnetic, with susceptibility up to 940×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. The rock contains scattered altered tabular plagioclase phenocrysts up to 2.5 mm across and less common altered ferromagnesian phenocrysts up to 2 mm long. In addition, there are a few microphenocrysts of FeTi oxide (titanomagnetite) and quartz. There are also one or two glomeroporphyritic aggregates up to 5 mm across that are composed of plagioclase-ferromagnesian phase-FeTi oxide. Traces of relict zircon and apatite are associated with these aggregates. Relict shapes suggest that the ferromagnesian phase might have been pyroxene. The phenocrystal phases occur in a fine grained, holocrystalline groundmass that is rich in K-feldspar and plagioclase, with minor interstitial quartz, altered ferromagnesian material and traces of FeTi oxide. From the relict texture and inferred primary mineralogy, the rock is interpreted to represent a porphyritic quartz latite, perhaps emplaced as a shallow intrusive or lava.

b) Alteration and structure: The rock has undergone moderate to strong and pervasive alteration, maybe as a result of very low grade metamorphism. All plagioclase has been albitised and there is minor flecking by sericite and traces of chlorite. Groundmass K-feldspar is weakly pigmented by dusty hematite and also slightly altered to sericite and chlorite. All former ferromagnesian material has been replaced by chlorite, with associated traces of titanite and leucoxene. Although most FeTi oxide remains fresh, it is locally altered to leucoxene. The alteration assemblage is consistent with propylitic type.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There is a little disseminated relict igneous FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (albite) and K-feldspar each 40%, quartz 10%, chlorite 6% sericite 2%, FeTi oxide 1% and traces of leucoxene, titanite, hematite, zircon and apatite.

Interpretation and Comments: It is interpreted that the sample represents a porphyritic quartz latite, perhaps emplaced as a shallow intrusive or lava. It has undergone pervasive propylitic alteration. The original rock contained scattered phenocrysts of plagioclase and less common phenocrysts of a ferromagnesian phase (maybe pyroxene) and microphenocrysts of FeTi oxide and quartz. There are also one or two glomeroporphyritic aggregates of plagioclase-ferromagnesian phase-FeTi oxide. Phenocrystal phases occur in a fine grained, holocrystalline groundmass dominated by K-feldspar and plagioclase, with minor quartz and

ferromagnesian material. Alteration has resulted in partial replacement of the igneous minerals by albite, chlorite and a little sericite, leucoxene and titanite.

378130 TS

Summary: Very strongly altered porphyritic felsic volcanic rock, maybe representing a lava. The original rock may have had scattered feldspar and a few ferromagnesian phenocrysts, set in a fine grained quartzofeldspathic groundmass. The rock has undergone complete replacement by a phyllic assemblage, maybe as a result of hydrothermal alteration. There has been recrystallisation to an assemblage of quartz and subordinate sericite, with traces of leucoxene. Minor clay (possibly kaolinite) occurs at several altered feldspar sites and could be partly the result of later imposed weathering. The latter process has given rise to local goethite staining.

Handspecimen: The sample is composed of a massive, slightly weathered, buff-coloured altered porphyritic felsic igneous rock. There are scattered clay-altered feldspar phenocrysts up to 3 mm across in a fine grained altered quartzofeldspathic groundmass. It is likely that the rock has undergone pervasive alteration to sericite (-clay). Testing of the section offcut with sodium cobaltinitrite did not indicate the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, it is evident that the rock is very strongly altered, but relict porphyritic texture is moderately preserved. There are scattered pseudomorphs after former phenocrysts up to 2 mm long. Some of these pseudomorphs could represent former feldspar grains, whereas others could be after former ferromagnesian grains. The rock also has a few small pseudomorphs after former FeTi oxide grains and rare relict grains of zircon. An altered and recrystallised groundmass component occupies at least 90% of the sample. It was probably fine grained (?aphanitic) and of quartzofeldspathic composition. The relict texture and interpreted primary mineralogy of the sample suggest that it represent an altered porphyritic felsic volcanic rock, maybe emplaced as a lava.

b) Alteration and structure: The original volcanic rock has been very strongly altered, likely to be as a result of hydrothermal processes. All groundmass material has been altered and recrystallised to an inequigranular fine to medium grained aggregate of quartz, with subordinate fine grained sericite. Former feldspar phenocrysts have been replaced by sericite and/or low-birefringent clay (e.g. kaolinite) and former ?ferromagnesian grains have been replaced by sericite and traces of leucoxene. Original igneous FeTi oxide grains have been replaced by leucoxene. In the altered groundmass, there are scattered alteration patches up to 1 mm across consisting of crystalline quartz, with local fine grained sericite infill. The alteration assemblage in the sample is of phyllic type and the altered rock has been cut by rare thin (<0.1 mm wide) veins of quartz. Slight weathering effects imposed on the rock are manifest by local goethite staining and a few small goethite aggregates, and the possible degradation of former feldspar phenocrysts to clay.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: quartz 70%, sericite 27%, clay 2% and traces of leucoxene, zircon and goethite.

Interpretation and Comments: It is interpreted that the sample is a very strongly altered porphyritic felsic volcanic rock. The original rock may have had scattered feldspar and a few ferromagnesian phenocrysts, set in a fine grained quartzofeldspathic groundmass, and could represent a former lava. It has undergone complete replacement by a phyllic assemblage, maybe as a result of hydrothermal alteration. There has been recrystallisation to an assemblage of quartz and subordinate sericite, with traces of leucoxene. Minor clay (possibly kaolinite) occurs at several altered feldspar sites and could be partly the result of later imposed weathering. The latter process has given rise to local goethite staining.

378131 TS

Summary: Altered porphyritic felsic volcanic rock, maybe representing a lava. The original rock contained scattered large quartz phenocrysts along with less common feldspar and ferromagnesian phenocrysts in a fine grained quartzofeldspathic groundmass. There has been very strong alteration imposed, probably due to hydrothermal processes, leading to replacement of groundmass, feldspar and ferromagnesian materials by quartz and sericite, with traces of leucoxene/rutile and tourmaline. The altered rock has been cut by a few veins, with early thin quartz veins cut by later sub-planar tourmaline-pyrite-quartz veins.

Handspecimen: The sample is composed of a relatively massive, buff-coloured, strongly altered, porphyritic fine grained felsic igneous rock. There are scattered relict quartz phenocrysts up to 4 mm across set in a fine grained altered quartzofeldspathic groundmass that probably contains much alteration-derived sericite. The altered rock has been cut by a couple of sub-parallel, near-planar veins up to 2 mm wide that contain aggregates of pyrite, a dark green/black silicate (?tourmaline) and minor quartz. Testing of the section offcut with sodium cobaltinitrite did not indicate the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. There are scattered, variably embayed, relict phenocrysts of quartz up to 4 mm across, along with less common pseudomorphs after elongate ferromagnesian phenocrysts (up to 2.5 mm long) and a tabular phase, probably feldspar phenocrysts, up to 4 mm long. There are also rare pseudomorphs after former microphenocrysts of FeTi oxide and a trace of relict prismatic apatite. Some of the ferromagnesian phenocrysts could have been biotite, and others maybe pyroxene, judging by relict grain shapes of pseudomorphs. In a few of these pseudomorphs, there are a few relict grains of zircon. An altered and recrystallised groundmass component occupies 75-80% of the rock. It was originally fine grained (?aphanitic) and probably quartzofeldspathic in composition. The relict texture and interpreted primary mineralogy imply that the rock may represent an altered porphyritic felsic volcanic, perhaps originally a lava.

b) Alteration and structure: There was very strong and pervasive alteration imposed on the rock, along with minor veining, almost certainly as a result of hydrothermal processes. Original feldspar grains have been replaced by fine grained sericite and ferromagnesian grains by sericite and a little leucoxene/rutile, plus a trace of tourmaline. The groundmass has been entirely replaced by fine grained inequigranular quartz, with subordinate amounts of sericite and traces of leucoxene/rutile (including replacements of FeTi oxide grains). The altered rock has been cut by two sets of veins. An earlier vein generation is expressed by thin (<0.2 mm wide) quartz-rich veins. These have been cut by later sub-planar veins up to 2 mm wide that are composed of fine to medium grained granular to prismatic tourmaline, scattered aggregates of fine to medium grained pyrite and a little quartz. The alteration assemblage in the sample is viewed as being of phyllic type.

c) Mineragraphy and paragenesis: Scattered aggregates of fine to medium grained pyrite up to a few millimetres long occur in the tourmaline-rich veins.

Mineral Mode: Approximate modal proportions are: quartz 65%, sericite 30%, tourmaline 3%, leucoxene/rutile and traces of zircon and apatite.

Interpretation and Comments: It is interpreted that the sample represents a porphyritic felsic volcanic rock, maybe emplaced as a lava, that has undergone very strong hydrothermal alteration and minor veining. The original rock contained scattered large quartz phenocrysts along with less common feldspar and ferromagnesian phenocrysts in a fine grained quartzofeldspathic groundmass. Alteration has been of phyllic type, leading to replacement of groundmass, feldspar and ferromagnesian materials by quartz and sericite, with traces of

leucoxene/rutile and tourmaline. The altered rock has been cut by a few veins, with early thin quartz veins cut by later sub-planar tourmaline-pyrite-quartz veins.

378132 TS

Summary: Porphyritic and weakly amygdaloidal quartz latite, perhaps emplaced originally as a lava. It contained scattered phenocrysts of plagioclase and a ferromagnesian phase, plus a few microphenocrysts of FeTi oxide and quartz in a fine grained quartzofeldspathic groundmass rich in K-feldspar. The rock has been altered to a propylitic assemblage, with partial replacement of igneous minerals by albite, chlorite, carbonate, sericite and trace leucoxene. Amygdules and uncommon veinlike aggregates contain quartz, carbonate and chlorite. There are two types of carbonate as part of the alteration assemblage; one is brownish and Fe-bearing, the other may be more dolomitic.

Handspecimen: The sample is composed of a massive, pale brown altered fine grained porphyritic intermediate to felsic igneous rock. It contains a few altered feldspar phenocrysts up to 3 mm across and diffuse green and white patches up to a few millimetres across that might represent altered ferromagnesian grains as well as possible amygdules. The green material might include chlorite and sericite, whereas the white material is carbonate. Testing of the section offcut with dilute HCl gave a slow reaction, suggesting that the carbonate may be dolomitic. Staining of the section offcut with sodium cobaltinitrite showed that there is abundant K-feldspar in the groundmass. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic and amygdular textures are moderately well preserved, despite strong alteration. The rock contains scattered altered tabular plagioclase phenocrysts up to 3 mm across and less common altered ferromagnesian phenocrysts up to 2 mm long, with which are associated traces of relict apatite. In addition, there are a few altered FeTi oxide and relict quartz microphenocrysts. The phenocrystal phases occur in a fine grained, perhaps aphanitic and locally slightly flow foliated quartzofeldspathic groundmass in which there is a little altered ferromagnesian material and trace FeTi oxide. Uncommon ovoid amygdules up to 3 mm across are scattered sparsely in the groundmass. The relict texture and inferred primary mineralogy implies that the rock is an altered porphyritic quartz latite, maybe representing a lava originally.

b) Alteration and structure: The rock has undergone strong and pervasive alteration, with minor veining. All plagioclase has been albitised, with further replacement by sericite, chlorite and turbid yellow-brown Fe-bearing carbonate. All ferromagnesian material has been replaced by assemblages of chlorite \pm quartz \pm Fe-carbonate \pm leucoxene, although some ferromagnesian grains have also been pseudomorphed by sericite. Grains of igneous FeTi oxide have been altered to leucoxene \pm sericite \pm Fe-carbonate. In the groundmass, there has been fine grained recrystallisation to dominant K-feldspar, with minor quartz, albite, chlorite, Fe-carbonate and traces of sericite and leucoxene. Amygdules have been filled by fine to medium grained quartz, chlorite and commonly Fe-carbonate and a colourless carbonate (e.g. dolomitic). The altered rock has been cut by a few veins, one type containing dominant carbonates plus chlorite and quartz, and the other thinner type containing fine grained quartz \pm sericite. The alteration and vein assemblages are consistent with propylitic type.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: K-feldspar 50%, plagioclase (albite) 20%, quartz and carbonates (Fe-bearing, dolomite) each 10%, chlorite 7% sericite 3% and traces of leucoxene and apatite.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic and weakly amygdaloidal quartz latite, perhaps emplaced originally as a lava. It contained scattered phenocrysts of plagioclase and a ferromagnesian phase, plus a few microphenocrysts of FeTi oxide and quartz in a fine grained quartzofeldspathic groundmass rich in K-feldspar. Propylitic alteration has occurred, with partial replacement of igneous

minerals by albite, chlorite, carbonate, sericite and trace leucoxene. Amygdules and uncommon veinlike aggregates contain quartz, carbonate and chlorite. There are two types of carbonate as part of the alteration assemblage; one is brownish and Fe-bearing, the other may be more dolomitic.

378133 TS

Summary: Strongly altered porphyritic felsic volcanic rock, probably representing a former amygdaloidal lava. The rock contains scattered variably altered plagioclase phenocrysts and a few quartz microphenocrysts in a fine grained altered and recrystallised quartzofeldspathic groundmass. Alteration may have been due to hydrothermal processes and has caused the patchy replacement and veining of the groundmass by fine to medium grained quartz and a minor sericite. Amygdular patches have been filled by quartz, with the remainder of the groundmass having been replaced by fine grained K-feldspar, plus minor albite, quartz and sericite. Plagioclase phenocrysts have been variably replaced by albite and sericite.

Handspecimen: The sample is composed of a rather massive, altered pale buff coloured porphyritic felsic volcanic rock. It contains scattered altered feldspar phenocrysts up to 2-3 mm across set in a fine grained quartzofeldspathic groundmass. The latter may be partly sericitised and also contains a few fine grained quartz patches and veinlets. Staining of the section offcut with sodium cobaltinitrite showed that there is abundant K-feldspar in the groundmass. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic and possible amygdular textures are moderately well preserved. There are scattered variably altered plagioclase phenocrysts up to 1.5 mm across and a few possible microphenocrysts of quartz, plus rare pseudomorphs after microphenocrysts of ferromagnesian material and FeTi oxide. The phenocrystal phases occur in an altered and recrystallised fine grained quartzofeldspathic groundmass. The latter does not display any evidence for it having been fragmental and it was probably of aphanitic character. There are, however, scattered possible ovoid to irregular amygdules up to 1.5 mm across throughout. The relict texture and interpreted primary mineralogy suggests that the sample represents a porphyritic and amygdular felsic lava.

b) Alteration and structure: There has been strong pervasive alteration, maybe as a result of hydrothermal processes. The groundmass has finely recrystallised to a dominant assemblage of K-feldspar, with lesser amounts of albite, quartz and sericite, plus a trace of leucoxene. The groundmass has been irregularly pervaded by patches up to a few millimetres across, and scattered thin veins, containing fine to medium grained quartz and minor sericite. Possible amygdules have been filled by medium grained quartz. Plagioclase phenocrysts have been variably altered to albite and sericite, with ferromagnesian grains replaced by sericite and leucoxene and FeTi oxide by leucoxene. The alteration assemblage is considered to be transitional between potassic and phyllic. There has been slight weathering of the sample, manifest by a little goethite staining.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: K-feldspar 40%, quartz 30%, plagioclase (including albite) 20%, sericite 10% and traces of leucoxene and goethite.

Interpretation and Comments: It is interpreted that the sample is a porphyritic felsic volcanic rock, most likely representing a lava. It has scattered plagioclase phenocrysts and possible quartz microphenocrysts, along with small amygdules set in a fine grained quartzofeldspathic groundmass. The rock has undergone strong alteration probably as a result of hydrothermal processes. There has been patchy replacement and veining of the groundmass by fine to medium grained quartz and a minor sericite. Amygdular patches have been filled by quartz, with the remainder of the groundmass having been replaced by fine grained K-feldspar, plus minor albite, quartz and sericite. Plagioclase phenocrysts have been variably replaced by albite and sericite. Alteration is viewed as being transitional between potassic and phyllic types.

378135 TS

Summary: Strongly altered porphyritic, fine grained felsic igneous rock, maybe representing a former lava. The original rock contained scattered feldspar phenocrysts, and possibly a few quartz phenocrysts and ferromagnesian microphenocrysts in a fine grained quartzofeldspathic groundmass. The rock has undergone strong phyllic alteration, maybe as a result of hydrothermal processes, with total recrystallisation of the groundmass to fine to medium grained inequigranular quartz and subordinate amounts of sericite.

Handspecimen: The sample is composed of a massive, altered porphyritic fine grained felsic igneous rock. It is pale buff in colour and contains scattered altered feldspar phenocrysts up to 3 mm across in a fine grained altered quartzofeldspathic groundmass. The feldspar phenocrysts appear to have been sericitised. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately preserved. There are scattered pseudomorphs after former tabular feldspar phenocrysts up to 3 mm long, a few possible recrystallised quartz phenocrysts up to 1 mm across and a few pseudomorphs after former microphenocrysts of a ferromagnesian phase, plus a trace of relict zircon. The phenocrystal phases occurred in an original fine grained groundmass of probable quartzofeldspathic composition. The groundmass does not have any indication that it was fragmentary so that the rock is interpreted as possibly representing a former felsic porphyritic lava.

b) Alteration and structure: There has been strong pervasive alteration, probably due to hydrothermal processes. There has been complete replacement of former feldspar phenocrysts by fine grained sericite \pm quartz and former ferromagnesian microphenocrysts have been replaced by sericite and a little leucoxene. The groundmass has been thoroughly recrystallised and totally replaced by dominant fine to medium grained inequigranular quartz, with minor interstitial and intergrown sericite and trace of leucoxene. In places in the altered groundmass, there are scattered irregular aggregates rich in quartz and in sericite (up to 2 mm across) into which crystalline quartz grains locally project. The sericite in these alteration patches is coarser grained than that replacing feldspar phenocrysts. The alteration is considered to be of pervasive strong phyllic type. Subsequently, the rock has been subjected to incipient weathering effects, manifest by local hematite staining and a few tiny aggregates of goethite.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: quartz 75%, sericite 24% and traces of leucoxene, zircon, hematite and goethite.

Interpretation and Comments: It is interpreted that the sample represents a strongly altered porphyritic felsic volcanic rock, probably a lava originally. It contained scattered feldspar phenocrysts, and possibly a few quartz phenocrysts and ferromagnesian microphenocrysts in a fine grained quartzofeldspathic groundmass. The rock has undergone strong phyllic alteration, maybe as a result of hydrothermal processes, with total recrystallisation and replacement of feldspar phenocrysts and groundmass to fine to medium grained inequigranular quartz and subordinate amounts of sericite, commonly in aggregates.

378136 TS

Summary: Porphyritic, fine grained felsic to intermediate igneous rock, maybe representing a former lava or shallow intrusive, with very strong alteration of phyllic type. The original rock contained scattered feldspar phenocrysts, and a few ferromagnesian microphenocrysts in a fine grained quartzofeldspathic groundmass. Alteration may be due to hydrothermal processes and has resulted in almost complete replacement of igneous materials by fine to medium grained quartz, sericite and traces of leucoxene and hematite. The altered groundmass has characteristic inequigranular quartz, with minor sericite, as well as a few coarser alteration aggregates of quartz and sericite.

Handspecimen: The sample is composed of a rather massive, strongly altered porphyritic fine grained ?intermediate to felsic igneous rock. It contains scattered pale green to grey sericitic pseudomorphs up to 3 mm across after former ?feldspar phenocrysts, set in a buff-coloured fine grained groundmass that might have been quartzofeldspathic in composition, but was subsequently sericitised. Testing of the section offcut with sodium cobaltinitride did not reveal the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately preserved. Judging by relict grain shape, the original rock contained scattered tabular feldspar phenocrysts up to 3 mm long and less common, smaller phenocrysts of a ferromagnesian phase. There may also have been a few glomeroporphyritic aggregates up to several millimetres across composed of feldspar, ferromagnesian material, FeTi oxide and trace zircon. The phenocrystal phases occurred in a fine grained, holocrystalline groundmass, probably of quartzofeldspathic composition and containing traces of FeTi oxide and zircon. The sample is interpreted, from the relict texture and inferred primary mineralogy, to represent a fine grained, porphyritic intermediate to felsic igneous rock, maybe emplaced as a lava or shallow intrusive.

b) Alteration and structure: The rock has undergone very strong pervasive phyllic alteration, maybe as a result of hydrothermal processes. All feldspar phenocrysts have been pseudomorphed by fine grained sericite and a little quartz, with ferromagnesian grains having been replaced by sericite and a little leucoxene, and FeTi oxide grains by leucoxene \pm hematite. In places in the groundmass, there are scattered alteration patches up to 1-2 mm across composed of medium grained quartz and sericite, with quartz crystals locally projecting into sericite masses. The alteration assemblage is similar to that observed in sample 378135.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: quartz 70%, sericite 29% and traces of leucoxene, zircon and hematite.

Interpretation and Comments: It is interpreted that the sample is a strongly altered porphyritic, fine grained felsic to intermediate igneous rock. It may represent a former lava or shallow intrusive. The original rock contained scattered feldspar phenocrysts, and a few ferromagnesian microphenocrysts in a fine grained quartzofeldspathic groundmass. Strong phyllic alteration may be due to hydrothermal processes and has resulted in almost complete replacement of igneous materials by fine to medium grained quartz, sericite and traces of leucoxene and hematite. The altered groundmass has characteristic inequigranular quartz, with minor sericite, as well as a few coarser alteration aggregates of quartz and sericite.

378137 TS

Summary: Coarse grained lithic-crystal felsic tuff or derived epiclastic sandstone (grading into conglomerate). Relict textures are not diagnostic to distinguish due to alteration and recrystallisation. The rock has abundant lithic clasts that include volcanic material (pumice and porphyritic grains) as well as fine grained low grade metasedimentary material (mica schist, etc.). There are also individual mineral grains dominated by former volcanic-sources quartz and plagioclase. The matrix interstitial to lithic and mineral grains is composed largely of former fine pumiceous material. The rock has undergone strong alteration of propylitic type, with replacement by albite and lesser amounts of quartz, K-feldspar, sericite and chlorite. A few thin veins cut the altered rock and contain quartz \pm albite, chlorite. The rock has been weakly deformed, with slight development of a foliation defined by preferred orientation of alteration-derived sericite.

Handspecimen: The sample is composed of a massive to weakly foliated, coarse grained lithic sandstone, grading to conglomerate. It contains scattered lithic clasts up to 1 cm across and individual grains of quartz and feldspar up to 3 mm across in a finer grained grey matrix. Lithic include fine grained dark grey sedimentary types (e.g. shale, siltstone) as well as volcanic types. The rock may have undergone some alteration to sericite and chlorite. Staining of the section offcut with sodium cobaltinitrite showed that many of the lithic clasts contain significant K-feldspar, but that there is little K-feldspar in the matrix. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict texture is moderately preserved. It is apparent that the rock is clastic, but the preserved textures are not diagnostic as to whether the rock is dominantly pyroclastic or that the components have undergone transport and deposition to form a coarse epiclastic sandstone (-conglomerate). The rock contains abundant lithic clasts up to 1 cm across, as well as individual mineral grains. These are relatively tightly packed, but there is a subordinate amount of fine to medium grained matrix material. Lithic clasts are varied and include elongate, commonly foliated low grade metasedimentary types (e.g. former shale or siltstone that has been metamorphosed into slate or muscovite-quartz schist) as well as volcanic types. The latter were mostly pumice, although some are porphyritic (plagioclase phenocrysts in a fine grained groundmass). Individual mineral grains are dominated by former volcanic-sourced quartz and plagioclase up to 1.5 mm across, plus rare K-feldspar, muscovite, biotite and tourmaline. The matrix is apparently composed of fine to medium grained former pumiceous material, including altered glass shards. From the relict texture, the rock is considered to be a lithic-crystal felsic tuff or derived epiclastic sandstone (-conglomerate).

b) Alteration and structure: The rock has sustained strong and pervasive alteration and minor veining. All volcanic lithic material has been replaced by fine grained albite and lesser amounts of K-feldspar, quartz, sericite and chlorite, although some clasts are dominated by sericite alteration. Low grade metasedimentary lithics are dominated by muscovite/sericite and quartz. All plagioclase grains are altered to albite, with a little sericite and matrix material has been finely recrystallised, with replacement by albite, chlorite, quartz, sericite and traces of leucoxene. The alteration assemblage is consistent with propylitic type. Minor veining has occurred, with emplacement of a couple of irregular veins up to 0.2 mm wide that are dominated by quartz, but also contain minor albite and chlorite. An incipient foliation has formed in the rock, and is defined by preferred orientation of some lithic clasts and by alteration-derived sericite aggregates. Slight weathering effects are indicated by a few small goethite aggregates and staining.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 50%, quartz 20%, sericite + muscovite 13%, K-feldspar 10%, chlorite 6% and traces of leucoxene, biotite, tourmaline and goethite.

Interpretation and Comments: It is interpreted that the sample is an altered coarse grained lithic-crystal felsic tuff or derived epiclastic sandstone (grading into conglomerate). Relict textures are not diagnostic to distinguish due to alteration and recrystallisation. The rock has abundant lithic clasts that include volcanic material (pumice and porphyritic grains) as well as fine grained low grade metasedimentary material (mica schist, etc.). There are also individual mineral grains dominated by former volcanic-sources quartz and plagioclase. The matrix interstitial to lithic and mineral grains is composed largely of former fine pumiceous material. The alteration imposed is of strong propylitic type, with replacement by albite and lesser amounts of quartz, K-feldspar, sericite and chlorite. A few thin veins cut the altered rock and contain quartz \pm albite, chlorite. The rock has been weakly deformed, with slight development of a foliation defined by preferred orientation of alteration-derived sericite and elongate lithic clasts.

378138 TS

Summary: Well laminated shale-siltstone, with good preservation of detrital grains and sedimentary bedding. Laminations are planar and sharp to gradational, with detrital grains dominated by plagioclase, K-feldspar, quartz and fine grained lithics. Matrix to the coarser laminae, as well as the finer, shaly laminae, is dominated by chlorite, with patchy development of carbonate. Shaly laminae may contain a little carbonaceous material and traces of pyrite. Alteration in the rock may be due to very low grade metamorphism and is dominated by an assemblage of albite, chlorite and carbonate, with a little sericite.

Handspecimen: The sample is composed of a well laminated, fine grained shale-siltstone. Paler grey laminae are slightly coarser grained (siltstone) and are intercalated with darker grey shaly laminae. Bedding laminations are planar and on a scale of <0.5 mm to 2 cm. The rock is probably quartzofeldspathic in composition, with shaly laminae possibly have a carbonaceous component. Staining of the section offcut with sodium cobaltinitrite showed that a moderate amount of K-feldspar is present throughout. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture and sedimentary bedding laminations are well preserved. There are intercalated fine grained shaly laminae with coarser laminae that grade from siltstone into fine sandstone. Laminations are on a scale of <0.5 mm to 2 cm in thickness. The somewhat coarser laminae are dominated by angular detrital grains of plagioclase, K-feldspar, quartz and lithics (probably of fine grained volcanic origin), with traces of detrital biotite, muscovite and leucoxene. Maximum detrital grainsize is up to 0.5 mm, but most detrital grains are <0.2 mm across. The matrix interstitial to detrital grains in fine grained and dominated by alteration-derived chlorite, carbonate and a little sericite and trace leucoxene and pyrite. The shaly laminae contain a higher proportion of chlorite and smaller amounts of feldspars and quartz. They are more darkly pigmented by fine carbonaceous material and also contain traces of fine grained disseminated pyrite.

b) Alteration and structure: The rock has undergone moderate alteration, interpreted to be a result of very low grade metamorphism. This has led to albitisation of plagioclase and its further partial replacement by sericite, chlorite and carbonate. Matrix chlorite and carbonate developed during alteration, with some of the siltstone laminae containing considerable carbonate, in places as a replacement of detrital grains. Finer grained laminae have locally developed a weak, bedding plane parallel fissility. Possible former organic material has matured into a carbonaceous substance and traces of fine grained pyrite have formed.

c) Mineragraphy and paragenesis: The sample contains traces of fine grained disseminated pyrite, interpreted to be a product of alteration.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 30%, chlorite 25%, K-feldspar and carbonate each 15%, quartz 10%, sericite/muscovite 3%, carbonaceous material 1% and traces of leucoxene, biotite and pyrite.

Interpretation and Comments: It is interpreted that the sample is a very low grade metamorphosed, well laminated sedimentary rock, e.g. shale-siltstone, There is strong preservation of detrital grains and sedimentary bedding. Laminations are planar and sharp to gradational, with detrital grains dominated by plagioclase, K-feldspar, quartz and fine grained lithics. Matrix to the coarser laminae, as well as the finer, shaly laminae, is dominated by chlorite, with patchy development of carbonate. Shaly laminae may contain a little carbonaceous material and traces of pyrite. Alteration in the rock is dominated by an assemblage of albite, chlorite and carbonate, with a little sericite and a trace of pyrite.

378139 TS

Summary: Coarse grained lithic-crystal felsic tuff, dominated by pumiceous fragments and a minor pumiceous matrix component. There is a minor population of other lithic fragments including foliated carbonaceous shale/siltstone and quartzite, as well as individual mineral grains dominated by volcanic quartz and plagioclase grains. There is little evidence for the volcanic components to have been reworked to form an epiclastic sandstone. The rock has undergone strong alteration that is interpreted to be transitional between propylitic and potassic. There has been replacement of former igneous components by albite, sericite, K-feldspar, quartz, chlorite, carbonate and traces of leucoxene and pyrite.

Handspecimen: The sample is composed of a massive to weakly foliated coarse grained felsic tuff or epiclastic sandstone. It contains scattered lithic fragments up to 1 cm across as well as individual grains of quartz and feldspar up to 3 mm across set in a grey, finer grained volcanoclastic matrix. The lithic fragments are commonly fine grained and dark grey and may represent a carbonaceous sedimentary type. However, some lithics are also likely to be volcanic fragments. The rock has undergone mild sericite-chlorite alteration and staining of the section offcut with sodium cobaltinitrite showed that a moderate amount of K-feldspar is present throughout. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict medium to coarse grained fragmental texture is moderately well preserved. The rock contains abundant tightly packed angular to sub-rounded lithic fragments up to 5 mm across and less abundant individual mineral grains, set in a relatively minor fine to medium grained matrix component of pumiceous material. Lithic grains are dominated by pumice fragments, with relict frothy and flow foliated textures and there are also a few porphyritic fragments (quartz and plagioclase phenocrysts). There is a smaller population of non-volcanic lithic fragments and these include fine grained foliated carbonaceous shale, grading into siltstone (with conspicuous muscovite) and medium grained muscovite quartzite. Individual mineral grains are dominated by former volcanic phenocrysts of quartz (some embayed) and plagioclase up to 2 mm across, along with rare grains of muscovite, altered ferromagnesian material (probably biotite and pyroxene, judging by relict grain shape), FeTi oxide and zircon. The finer grained pumiceous matrix locally preserves fine glass shard texture. There is little textural evidence for the components of the rock to have undergone sedimentary transport and deposition and hence it is interpreted that the rock is more likely to be a coarse grained lithic-crystal felsic tuff (i.e. a pyroclastic rock).

b) Alteration and structure: The volcanic rock has sustained strong pervasive alteration, maybe due to very low grade metamorphism and/or hydrothermal processes. Pumiceous fragments and matrix have been mostly replaced by fine grained albite, quartz, K-feldspar and less abundant sericite, carbonate, chlorite and traces of leucoxene and pyrite. However, some fragments are dominated by sericite and/or chlorite and a few contain large porphyroblastic aggregates of carbonate. Former plagioclase grains have been albitised and also flecked by sericite and carbonate. Former biotite has been replaced by sericite and leucoxene, pyroxene by carbonate, and FeTi oxide by leucoxene. A weak foliation has been imposed on the rock, defined by slight preferred orientation of elongate lithic fragments and by development of elongate and locally stylolitic masses rich in sericite. Alteration is viewed as being transitional in type between potassic and propylitic. Slight supergene oxidation in the sample is indicated by partial replacement of pyrite by goethite and by local goethite aggregates and staining.

c) Mineralogy and paragenesis: The sample contains traces of fine grained disseminated pyrite, interpreted to be a product of alteration.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 40%, quartz 20%, sericite + muscovite and K-feldspar each 15%, chlorite 5%, carbonate 4% and traces of carbonaceous material, leucoxene, zircon, goethite and pyrite.

Interpretation and Comments: It is interpreted that the sample is an altered coarse grained lithic-crystal felsic tuff, dominated by pumiceous fragments and a minor pumiceous matrix component. There is a minor population of other lithic fragments including foliated carbonaceous shale/siltstone and quartzite, as well as individual mineral grains dominated by volcanic quartz and plagioclase grains. There is little evidence for the volcanic components to have been reworked to form an epiclastic sandstone. Strong alteration imposed on the rock is interpreted to be transitional between propylitic and potassic types. There has been replacement of former igneous components by albite, sericite, K-feldspar, quartz, chlorite, carbonate and traces of leucoxene and pyrite.

378140 TS

Summary: Strongly altered medium to coarse grained lithic-crystal tuff, probably of intermediate to felsic composition. The rock contains abundant fine grained volcanic lithic fragments (mostly porphyritic, but some pumiceous), plus scattered altered plagioclase grains and rare quartz grains in a fine to medium grained pumiceous matrix. Pervasive strong alteration of transitional propylitic-potassic type has been imposed, with replacement by albite, K-feldspar, chlorite, carbonate, sericite and quartz. In places, porphyroblasts of carbonate have grown and there is a trace of disseminated pyrite as part of the alteration assemblage. The carbonate is Fe-bearing and slight weathering effects have led to partial replacement of carbonate (and pyrite) by goethite.

Handspecimen: The sample is composed of a massive, dark grey medium to coarse grained fragmental rock, possibly a tuff or epiclastic. It contains scattered altered feldspar grains up to 2 mm across as well as scattered fine grained pale grey to pinkish lithic fragments up to 8 mm across, all set in a fine grained feldspathic matrix. Staining of the section offcut with sodium cobaltinitrite showed that many fragments are rich in K-feldspar and that there is a moderate amount of K-feldspar in the matrix. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict volcanoclastic fragmental texture is relatively well preserved and there is no textural evidence to indicate that the rock represents a significantly reworked volcanoclastic, e.g. an epiclastic sandstone. The rock is dominated by rather tightly packed volcanic lithic fragments up to 5-6 mm across, with less abundant altered plagioclase grains, rare quartz, FeTi oxide and zircon grains, all enclosed in fine to medium grained pumiceous material forming the matrix. Volcanic fragments are angular to sub-rounded and are mostly fine grained and porphyritic (plagioclase-phyric), with feldspathic groundmass material, although some have a distinct relict pumice texture. The relict texture is interpreted to indicate that the rock represents a lithic-crystal tuff of intermediate to felsic volcanic composition.

b) Alteration and structure: There has been strong and pervasive alteration, maybe as a result of very low grade metamorphism. All plagioclase grains have been replaced by albite, with minor carbonate and sericite. All pumiceous matrix material has been replaced by fine grained K-feldspar, albite, chlorite, sericite and minor quartz, carbonate and trace rutile and pyrite. Fine grained groundmass material in fragments has been replaced by K-feldspar and/or albite, with minor quartz and carbonate. Igneous FeTi oxide has been replaced by rutile. Scattered throughout the rock and overgrowing fragments and matrix are irregular carbonate porphyroblasts up to 3 mm across. It is likely that the carbonate is an Fe-bearing type, e.g. ankerite, siderite. The altered rock has been cut by a few thin veins up to 0.05 mm wide. This include early anastomosing veins of sericite and later sub-planar veins of quartz + sericite. The alteration assemblage in the sample is viewed as being of transitional propylitic to potassic type. Slight weathering effects have been imposed, leading to local replacement of carbonate and pyrite by goethite.

c) Mineragraphy and paragenesis: The sample contains traces of disseminated pyrite, interpreted to be a product of alteration. Largest grains are up to 0.3 mm across.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 50%, K-feldspar 25%, chlorite 8%, carbonate 6%, quartz 5%, sericite 4%, goethite 1% and traces of rutile, zircon and pyrite.

Interpretation and Comments: It is interpreted that the sample is a strongly altered medium to coarse grained lithic-crystal tuff of intermediate to felsic composition. The rock contains abundant fine grained volcanic lithic fragments (mostly porphyritic, but some pumiceous), plus scattered altered plagioclase grains and rare quartz grains in a fine to medium grained

pumiceous matrix. Pervasive strong alteration of transitional propylitic-potassic type has been imposed, with replacement by albite, K-feldspar, chlorite, carbonate, sericite and quartz. In places, porphyroblasts of Fe-bearing carbonate have grown and there is a trace of disseminated pyrite as part of the alteration assemblage.

378141 TS

Summary: Massive, medium to coarse grained feldspathic-lithic sandstone, evidently from an intermediate volcanic (e.g. andesitic) provenance. The rock contains abundant altered angular detrital grains of plagioclase and volcanic lithics, with minor altered ferromagnesians and a little FeTi oxide and quartz. There has been strong pervasive alteration, probably caused by very low grade metamorphism, with replacement by an assemblage dominated by albite and chlorite, with a little sericite, carbonate and leucoxene.

Handspecimen: The sample is composed of a massive, speckled pink and dark green coloured, altered medium to coarse grained volcanoclastic rock. It contains abundant feldspar grains (plagioclase) up to 5 mm across and less common fine grained lithic grains up to 7 mm across in a fine grained chloritic matrix. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The sample is weakly magnetic, with susceptibility of up to 70×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict medium to coarse grained detrital grain texture is well preserved. The rock is a massive, feldspathic-lithic sandstone with rather tightly packed angular detrital grains up to 5 mm across enclosed in a subordinate fine grained matrix component. Altered plagioclase is the most abundant detrital grain type and there are scattered lithics (porphyritic and sub-trachytic textured, and locally aphanitic intermediate volcanic material), a few altered ferromagnesian grains (possibly originally pyroxene judging by relict grain shape), FeTi oxide and quartz, with a trace of zircon. The fine grained matrix constitutes about 30-40 volume % interstitial to the detrital grains. It is interpreted to represent fine grained altered volcanoclastic silty-muddy material.

b) Alteration and structure: The rock has undergone moderate to strong and pervasive alteration, probably as a result of very low grade metamorphism. All plagioclase has been albitised, with further replacement by fine grained sericite and slight pigmentation by hematite. The fine grained matrix component, groundmass component of volcanic lithic grains and former ferromagnesian grains have been largely replaced by chlorite, in places with minor fine grained carbonate and traces of leucoxene and sericite. Detrital FeTi oxide grains have been largely replaced by leucoxene \pm hematite. The rock has been cut by a couple of thin, planar shear/cataclastic zones as well as by rare thin veins containing one or more of quartz, albite and chlorite.

c) Mineralogy and paragenesis: No sulphide minerals have been observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 60%, chlorite 32%, sericite 3%, carbonate 2%, quartz and leucoxene each 1% and traces of FeTi oxide, hematite and zircon.

Interpretation and Comments: It is interpreted that the sample represents a feldspathic-lithic sandstone of medium to coarse grain size, with a provenance dominated by andesitic volcanic material. The rock contains abundant altered angular detrital grains of plagioclase and volcanic lithics, with minor altered ferromagnesians and a little FeTi oxide and quartz. There has been strong pervasive alteration, probably caused by very low grade metamorphism, with replacement by an assemblage dominated by albite and chlorite, with a little sericite, carbonate and leucoxene.

378142 TS

Summary: Porphyritic quartz micromonzonite, probably representing a shallow intrusive rock. It contained scattered phenocrysts of plagioclase and ferromagnesian material in a fine to medium grained groundmass of K-feldspar, plagioclase, quartz, ferromagnesian material and FeTi oxide. There are a few glomeroporphyritic aggregates of plagioclase, ferromagnesian material, FeTi oxide and trace apatite. The rock has undergone rather strong propylitic alteration, with replacement by an assemblage of albite, chlorite, actinolite and sericite. Weathering effects have led to further degradation to nontronite and goethite.

Handspecimen: The sample is composed of a massive, fine to medium grained felsic igneous rock. It contains scattered tabular plagioclase phenocrysts up to 5 mm across and dark greenish altered ferromagnesian grains in a fine to medium grained quartzofeldspathic groundmass. Ferromagnesian grains appear to be chloritised. Staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant in the groundmass. The sample contains minor magnetite and is moderately to strongly magnetic, with susceptibility of up to 1110×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. The rock contains scattered, largely altered tabular phenocrysts of plagioclase up to 3.5 mm across, with less common and smaller altered phenocrysts of ferromagnesian material up to 2 mm long. The phenocryst phases are set in a fine to medium grained (up to 0.5 mm grainsize) groundmass of inequigranular K-feldspar, plagioclase and quartz, with minor altered ferromagnesian material, FeTi oxide (e.g. titanomagnetite) and a trace of apatite. In the groundmass, there are a few glomeroporphyritic aggregates of plagioclase + altered ferromagnesian material + FeTi oxide \pm trace apatite up to several millimetres across. Relict shapes suggest that ferromagnesian phenocrysts could have included hornblende and pyroxene, whereas in the groundmass, it is possible that biotite could have been present. The relict texture and inferred primary mineralogy imply that the rock represents a porphyritic quartz micromonzonite, probably emplaced as a shallow intrusive.

b) Alteration and structure: The rock has undergone moderate to strong, pervasive alteration of propylitic type, probably as a result of very low grade metamorphism, followed by the imposition of weathering effects. Plagioclase has been largely albitised, with further replacement by fine grained sericite and a little chlorite. Ferromagnesian phenocrysts have been replaced by chlorite and/or actinolite, with traces of leucoxene, whereas biotite has been replaced by chlorite. Igneous FeTi oxide is slightly altered to hematite and the latter phase has also finely dusted relict K-feldspar. The rock has sustained mild weathering effects, with development of goethite staining and the partial degradation of altered ferromagnesian material to khaki coloured nontronite.

c) Mineragraphy and paragenesis: No sulphide minerals have been observed in the sample, but there is a little relict disseminated FeTi oxide (e.g. titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (mostly albite) 35%, K-feldspar 30%, quartz 15%, chlorite 10%, actinolite, sericite, goethite and nontronite each 2%, FeTi oxide 1% and traces of leucoxene, apatite and hematite.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic quartz micromonzonite, probably representing a shallow intrusive rock. It contained scattered phenocrysts of plagioclase and ferromagnesian material in a fine to medium grained groundmass of K-feldspar, plagioclase, quartz, ferromagnesian material and FeTi oxide. There are a few glomeroporphyritic aggregates of plagioclase, ferromagnesian material, FeTi oxide and trace apatite. There has been rather strong propylitic alteration, with replacement by an assemblage of albite, chlorite, actinolite and sericite. Weathering effects have led to further degradation to nontronite and goethite.

378143 TS

Summary: Porphyritic microgranodiorite with moderate to strong propylitic alteration. The rock contains scattered plagioclase phenocrysts and less common altered ferromagnesian phenocrysts and a few small quartz phenocrysts in a fine to medium grained, holocrystalline, inequigranular groundmass of plagioclase, K-feldspar, quartz, altered ferromagnesian material and disseminated FeTi oxide. There is no textural evidence for the rock to represent an epiclastic sandstone. There has been pervasive alteration, with partial replacement of plagioclase by albite, chlorite and sericite, and ferromagnesian by chlorite and sericite. A few scattered quartz aggregates in the groundmass may also be due to alteration. Weathering effects have caused local goethite staining.

Handspecimen: The sample is composed of a massive, porphyritic, fine to medium grained, pale pink-grey felsic igneous rock. It contains scattered tabular feldspar phenocrysts up to 3 mm across in a fine to medium grained quartzofeldspathic groundmass in which there are small chloritised ferromagnesian grains. Staining of the section offcut with sodium cobaltinitrite showed that there is a moderate amount of K-feldspar in the groundmass. The sample contains a little disseminated magnetite and is moderately magnetic, with susceptibility of up to 620×10^{-5} SI units. Slight weathering effects have led to local goethite staining.

Petrographic Section:

a) Primary mineralogy and textures: In the section, it is evident that the rock is a porphyritic igneous type. There is no textural indication that the rock is of detrital origin (e.g. epiclastic sandstone). Although there has been rather strong pervasive alteration, relict textures are moderately well preserved. There are scattered partly altered tabular plagioclase phenocrysts up to 2.5 mm across, a few altered ferromagnesian phenocrysts up to 1.5 mm across and uncommon quartz phenocrysts up to 1 mm across, all set in a holocrystalline, fine to medium grained (typically up to 0.4 mm), inequigranular groundmass of plagioclase, K-feldspar, quartz, altered ferromagnesian material and a little disseminated FeTi oxide (e.g. titanomagnetite). Quartz tends to occupy interstitial positions in the groundmass. From the relict texture and inferred primary mineralogy, the rock is considered to represent a porphyritic microgranodiorite. It may have been emplaced as a shallow intrusive.

b) Alteration and structure: The rock has been pervasively altered, with moderate to strong replacement by a propylitic assemblage. Plagioclase has been partly albitised, with further replacement by chlorite and sericite. All ferromagnesian material has been replaced by chlorite and/or sericite, with a little titanite having formed by alteration of igneous FeTi oxide. In the groundmass, there are scattered polycrystalline fine to medium grained aggregates of quartz up to 2 mm across that may have formed by alteration. Slight weathering effects have been imposed on the sample and have resulted in patchy goethite staining.

c) Mineragraphy and paragenesis: No sulphide minerals have been observed in the sample. There is a little relict igneous FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (including albite) 50%, K-feldspar 20%, quartz 15%, chlorite 8%, sericite 5%, FeTi oxide and goethite each 1% and a trace of titanite.

Interpretation and Comments: It is interpreted that the sample represents a porphyritic microgranodiorite, perhaps emplaced as a shallow intrusive. There is no textural evidence for the rock to represent an epiclastic sandstone. The rock contains scattered plagioclase phenocrysts and less common altered ferromagnesian phenocrysts and a few small quartz phenocrysts in a fine to medium grained, holocrystalline, inequigranular groundmass of plagioclase, K-feldspar, quartz, altered ferromagnesian material and disseminated FeTi oxide. There has been pervasive propylitic alteration, with partial replacement of plagioclase by

albite, chlorite and sericite, and ferromagnesian by chlorite and sericite. A few scattered quartz aggregates in the groundmass may also be due to alteration. Weathering effects have caused local goethite staining.

378144 TS

Summary: Altered porphyritic rhyodacite or quartz latite, originally containing phenocrysts and small glomeroporphyritic aggregates of plagioclase, ferromagnesian minerals (most likely pyroxene and biotite) and FeTi oxide in a fine to medium grained, holocrystalline groundmass dominated by K-feldspar and quartz. The rock has undergone very low grade metamorphism (and/or propylitic alteration) to yield an assemblage dominated by albite and chlorite, with a little sericite and traces of hematite, titanite, epidote and leucoxene.

Handspecimen: The sample is composed of a moderately porphyritic felsic-intermediate igneous rock, with scattered altered plagioclase phenocrysts up to 5 mm across and smaller altered ferromagnesian phenocrysts in a fine grained, grey-pink feldspathic groundmass. The ferromagnesian material appears to have been altered to chlorite. Staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant in the groundmass. The sample contains minor magnetite as it is moderately magnetic, with susceptibility up to 510×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved despite moderate to strong pervasive alteration. The rock contains scattered altered tabular phenocrysts of plagioclase up to 4 mm long as well as less common altered phenocrysts of ferromagnesian phases up to 3 mm long. Relict shapes of the latter imply that pyroxene would have been the most common phase, although there are pseudomorphs after former flaky biotite grains up to 1 mm across. It is possible that some of the altered ferromagnesian material could also represent former hornblende grains. Microphenocrysts of FeTi oxide (e.g. titanomagnetite) are scattered. The rock contains a few glomeroporphyritic aggregates (tending into small enclaves) up to several millimetres across). These are composed of medium grained altered plagioclase and ferromagnesian material, with a little quartz and FeTi oxide and a trace of apatite. They could be of quartz microdiorite composition. Phenocryst phases and aggregates are set in a fine to medium grained holocrystalline groundmass composed largely of intergrown K-feldspar and quartz, with minor altered plagioclase and ferromagnesian material and a trace of finely disseminated FeTi oxide. Groundmass quartz occupies interstitial positions and is up to 0.5 mm across. From the preserved texture and the inferred primary mineralogy of the rock, it is considered to represent a porphyritic rhyodacite or quartz latite, perhaps being emplaced as part of a shallow intrusive.

b) Alteration and structure: The igneous rock has undergone pervasive moderate to strong alteration. All plagioclase has been albitised and also locally replaced by fine grained sericite and chlorite. All ferromagnesian material has been altered to chlorite, with former biotite also showing alteration to sericite. Traces of epidote, titanite and leucoxene are associated with altered ferromagnesian aggregates. Igneous FeTi oxide grains have been partly replaced by hematite \pm leucoxene and groundmass K-feldspar is slightly flecked by dusty hematite. The alteration assemblage is consistent with propylitic type, although it may simply be the product of very low grade metamorphism (e.g. lowermost greenschist facies). Slight weathering effects have caused local goethite staining, mainly at sites of altered ferromagnesian.

c) Mineragraphy and paragenesis: The sample contains a little relict igneous FeTi oxide. No sulphides have been observed.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 40%, K-feldspar 30%, quartz 15%, chlorite 10%, sericite 2%, FeTi oxide (titanomagnetite) and hematite each 1% and traces of titanite, leucoxene, epidote, apatite and goethite.

Interpretation and Comments: It is interpreted that the sample is a very low grade metamorphosed and/or propylitically altered porphyritic rhyodacite or quartz latite. It may

have been emplaced as a shallow intrusive. The original rock contained phenocrystal grains of plagioclase, pyroxene, biotite and FeTi oxide in a fine to medium grained groundmass dominated by K-feldspar and quartz. A few glomeroporphyritic aggregates of microdioritic composition are scattered. The rock has undergone pervasive alteration to albite and chlorite, with a little sericite, hematite, epidote, titanite and leucoxene.

378145 TS

Summary: Medium to coarse grained lithic-crystal felsic tuff, with strong and pervasive alteration of transitional phyllic-propylitic type. The rock has abundant relict volcanic quartz grains as well as altered lithic fragments, most of which were aphanitic/glassy and some porphyritic or pumiceous. All former lithic grains as well as uncommon feldspar, biotite and FeTi oxide grains have been replaced by fine grained sericite and chlorite, with a little quartz and leucoxene.

Handspecimen: The sample is composed of a speckled pale grey-green and dark green, medium to coarse grained fragmental textured rock, probably representing a type of felsic volcanoclastic. It contains scattered quartz grains up to 2 mm across and abundant altered lithic grains up to several millimetres across. The latter are fine grained and altered to chlorite and sericite. Slight surface weathering effects have led to development of local goethite staining. Testing of the section offcut with sodium cobaltinitrite did not indicate the presence of K-feldspar. The sample essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict texture is moderately well preserved despite strong pervasive alteration. There are abundant angular to rounded relict quartz grains up to 1.5 mm across, many of which have characteristics of volcanic quartz phenocrysts. There are also abundant angular altered lithic fragments up to several millimetres across. Many appear to have been aphanitic/glassy, but some have relict quartz phenocrysts and a few have textures suggesting that they were originally pumiceous. Some fragments locally show relict flow foliation. The rock has a few pseudomorphs after former tabular feldspar grains, rare pseudomorphs after former small grains of biotite and FeTi oxide, as well as traces of relict zircon. There is a minor matrix component of fine grained altered volcanoclastic material. The relict textures imply that the rock is an altered lithic-crystal tuff, evidently of felsic composition.

b) Alteration and structure: The original volcanoclastic rock has undergone strong pervasive alteration, e.g. by hydrothermal and/or low grade metamorphic effects. All former aphanitic/glassy/pumiceous material has been replaced by fine grained aggregates of sericite and chlorite, in places with a little quartz and traces of leucoxene. Former feldspar grains have been sericitised, former biotite grains altered to sericite and leucoxene and FeTi oxide replaced by leucoxene. Slight weathering effects have led to the development of local aggregates of goethite. The alteration assemblage is interpreted to be of transitional phyllic-propylitic type.

c) Mineralogy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: sericite 50%, quartz 30%, chlorite 19% and traces of leucoxene, zircon and goethite.

Interpretation and Comments: It is interpreted that the sample represents a medium to coarse grained lithic-crystal felsic tuff, with strong and pervasive alteration of transitional phyllic-propylitic type. The rock has abundant relict volcanic quartz grains as well as altered lithic fragments, most of which were aphanitic/glassy and some porphyritic or pumiceous. All former lithic grains as well as uncommon feldspar, biotite and FeTi oxide grains have been replaced by fine grained sericite and chlorite, with a little quartz and leucoxene.

378146 TS

Summary: Altered medium grained feldspathic-lithic (-quartz) sandstone, with a provenance from an intermediate to felsic volcanic source. The rock contains detrital grains of altered plagioclase, altered ferromagnesian material and minor lithics and quartz. Lithic grains include altered volcanic material. The rock has undergone very low grade metamorphism, leading to partial replacement of the primary components and development of an assemblage of albite, chlorite and sericite, with a trace of leucoxene. Slight supergene oxidation effects have led to local formation of goethite.

Handspecimen: The sample is composed of a khaki-coloured, massive, medium grained, feldspathic-lithic sandstone. It contains a few dark fine grained lithic grains up to 3 mm across, but most of the detrital grains are <1 mm across. Altered feldspar grains are abundant. The rock appears to be partly altered, with replacement by chlorite. It has also experienced weathering effects with development of slight goethite impregnation. Staining of the section offcut with sodium cobaltinitrite showed that there is a little K-feldspar. The sample is very weakly magnetic, with susceptibility of $\sim 30 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is moderately well preserved. The rock contains abundant altered detrital grains of plagioclase and ferromagnesian material up to 1.5 mm across, with less common quartz and lithic grains, a little K-feldspar and traces of muscovite, FeTi oxide, tourmaline and zircon. There is a relatively small matrix component that is finer grained and composed of the same material as the detrital grains, but is evidently more altered. Lithic grains are fine grained and include dark carbonaceous sedimentary material (e.g. carbonaceous shale), altered aphanitic volcanic material and fine grained quartzite. Relict shapes of ferromagnesian grains suggest that biotite was a dominant phase but that pyroxene and/or hornblende may also have been present. The rock is interpreted to be an altered medium grained feldspathic-lithic (-quartz) sandstone, with an intermediate to felsic volcanic provenance dominating. The source of the detritus is probably local as detrital grains are largely angular.

b) Alteration and structure: The sedimentary rock has undergone strong pervasive alteration, probably of propylitic type and likely to be due to very low grade metamorphism. Detrital plagioclase may have been albitised and also partly replaced by sericite and chlorite. Ferromagnesian material and volcanic lithic grains are altered to chlorite, with a little sericite and leucoxene. Matrix material is dominated by fine grained chlorite, with minor sericite and leucoxene. The rock has subsequently been slightly affected by supergene oxidation, with development of a few small aggregates of goethite and slight impregnation of alteration-derived chlorite by goethite.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (mostly albite) 45%, chlorite 33%, quartz 13%, sericite + muscovite 6%, K-feldspar and goethite each 1% and traces of FeTi oxide, leucoxene, tourmaline and zircon.

Interpretation and Comments: It is interpreted that the sample is an altered medium grained feldspathic-lithic (-quartz) sandstone, with a provenance from a local intermediate to felsic volcanic source. The rock contains angular detrital grains of altered plagioclase, altered ferromagnesian material and minor lithics and quartz. Lithic grains include altered volcanic material. The rock has undergone very low grade metamorphism, leading to partial replacement of the primary components and development of an assemblage of albite, chlorite and sericite, with a trace of leucoxene. Slight supergene oxidation effects have led to local formation of goethite.

378147 TS

Summary: Altered coarse grained intermediate volcanic tuff or epiclastic sandstone, probably of original andesitic to latitic composition. The rock contains tightly packed lithic fragments (porphyritic, aphanitic and locally pumiceous material) and mineral grains that include plagioclase (dominant), clinopyroxene and traces of brown hornblende, FeTi oxide and apatite. There has been strong alteration of transitional propylitic-potassic type, probably as a result of very low grade metamorphism, with considerable replacement of original igneous detritus by albite, K-feldspar and chlorite, with lesser amounts of carbonate and epidote, a little sericite and quartz and traces of hematite, pyrite, leucoxene and pumpellyite.

Handspecimen: The sample is composed of a massive, rather coarse grained fragmental intermediate to felsic volcanic rock (e.g. tuff) or epiclastic sandstone. It is speckled dark grey-green to yellow-grey in colour, with scattered lithic fragments up to 1 cm across of fine grained volcanic material and abundant altered feldspar grains. The rock is strongly altered, with development of abundant chlorite, plus minor sericite, epidote and a trace of hematite. Staining of the section offcut with sodium cobaltinitrite showed that there is a moderate amount of K-feldspar distributed throughout. The sample is very weakly magnetic, with susceptibility of $\sim 25 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, it is evident that the rock is a coarse grained volcanic fragmental. It contains scattered angular lithic fragments up to several millimetres across and abundant detrital mineral grains, in a finer grained volcaniclastic matrix. The lithic fragments are dominated by porphyritic intermediate volcanic rock (with scattered, variably altered phenocrysts of plagioclase and clinopyroxene up to 2 mm across in an altered groundmass) as well as smaller amounts of altered aphanitic and possibly pumiceous volcanic material. Detrital mineral grains are dominated by variably altered plagioclase, with minor clinopyroxene and a few grains of brown hornblende, FeTi oxide and apatite. It is interpreted from the relict texture and the mineralogical composition that the rock represents an altered coarse grained intermediate volcanic fragmental (tuff) or coarse epiclastic sandstone, with the material being of andesitic to latitic composition.

b) Alteration and structure: The rock has undergone strong pervasive alteration. Plagioclase has been partly albitised, but also locally replaced by K-feldspar, epidote, sericite, carbonate, chlorite and traces of quartz and pumpellyite. Ferromagnesian grains are partly replaced by carbonate and chlorite, with FeTi oxide replaced by hematite \pm leucoxene. Lithic fragments (especially fine grained groundmass material) and matrix have been replaced by variable amounts of albite, K-feldspar, chlorite, carbonate and epidote, with a little sericite, quartz, leucoxene, pyrite, pumpellyite and hematite. The altered groundmass of some lithic fragments is dominated by K-feldspar \pm albite, whereas in others, chlorite dominates. In places, there are substantial alteration aggregates up to a few millimetres across of carbonate, or of chlorite or epidote. The alteration effects are of transitional propylitic-potassic in character, but probably due to very low grade metamorphism. Slight weathering effects have led to local replacement of pyrite by goethite.

c) Mineragraphy and paragenesis: The sample contains traces of irregularly disseminated pyrite up to 0.2 mm across as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: plagioclase (mostly albite) 50%, K-feldspar 20%, chlorite 17%, epidote and carbonate each 4%, clinopyroxene 2%, quartz and sericite each 1% and traces of hornblende, FeTi oxide, leucoxene, hematite, pyrite, goethite, pumpellyite and apatite.

Interpretation and Comments: It is interpreted that the sample is an altered coarse grained intermediate volcanic tuff or epiclastic sandstone, probably of original andesitic to latitic composition. The rock contains tightly packed lithic fragments (porphyritic, aphanitic and

locally pumiceous material) and mineral grains that include plagioclase (dominant), clinopyroxene and traces of brown hornblende, FeTi oxide and apatite. There has been strong alteration of transitional propylitic-potassic type, probably as a result of very low grade metamorphism, with considerable replacement of original igneous detritus by albite, K-feldspar and chlorite, with lesser amounts of carbonate and epidote, a little sericite and quartz and traces of hematite, pyrite, leucoxene and pumpellyite.

378148 TS

Summary: Altered, moderately porphyritic felsic volcanic rock, probably representing a lava of dacitic composition. The original rock contained phenocrysts of plagioclase, plus a few of biotite, along with microphenocrysts of FeTi oxide and possible pyroxene in a fine grained (aphanitic/glassy) quartzofeldspathic groundmass. There is weak flow alignment of phenocrysts and of quartz-rich alteration patches in the groundmass. Pervasive strong alteration has led to replacement of the groundmass by K-feldspar, with minor quartz, sericite and hematite. Plagioclase has been replaced by variable amounts of quartz, K-feldspar, sericite and albite, with biotite being replaced by sericite \pm hematite \pm leucoxene, pyroxene by quartz \pm hematite, and FeTi oxide by hematite. The alteration may be due to low grade metamorphic effects and is of potassic-phyllic type.

Handspecimen: The sample is composed of a rather sparsely porphyritic, weakly flow foliated, dark brick red coloured felsic volcanic rock. It contains scattered altered feldspar phenocrysts up to 4 mm long set in a fine grained altered groundmass, strongly pigmented by fine grained hematite. The rock has a few aligned aggregates rich in quartz, but it is otherwise feldspar-rich, with sodium cobaltinitrite staining of the section offcut indicating that K-feldspar is abundant. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic and flow foliated texture is moderately well preserved. The original rock was evidently moderately porphyritic, with scattered feldspar phenocrysts (probably plagioclase) up to 4 mm long and less common biotite phenocrysts up to 2.5 mm long. There were scattered microphenocrysts of FeTi oxide up to 0.5 mm across and microphenocrysts of another ferromagnesian phase (possibly pyroxene judging by relict grain shape) up to 0.7 mm across, plus rare small grains of apatite and zircon. The phenocrystal phases were set in an originally fine grained (aphanitic to glassy) quartzofeldspathic groundmass containing a few small microphenocrysts of feldspar, biotite and FeTi oxide. In the groundmass, there are a few irregular to elongate, aligned aggregates rich in quartz. These might be due to replacement of former glassy bands. The pseudomorphs after former feldspar phenocrysts also show some alignment, interpreted as due to original flow in the magma. It is considered likely from the relict textures and interpreted primary mineralogy that the rock is an altered porphyritic biotite-pyroxene dacite, representing a lava.

b) Alteration and structure: The rock has been strongly and pervasively altered. This has led to replacement of the original aphanitic to glassy groundmass by fine grained K-feldspar, with minor quartz, sericite and hematite, along with development of elongate to irregular patches of fine to medium grained quartz. Former plagioclase phenocrysts were replaced by quartz, K-feldspar \pm albite, with subsequent variable replacement (of albite) by sericite. Biotite grains have been replaced by sericite \pm hematite \pm leucoxene, pyroxene by quartz \pm hematite and FeTi oxide by hematite. The alteration may be due to low grade metamorphism and occurred under oxidising conditions (presence of hematite). The alteration assemblage is of potassic-phyllic type.

c) Mineralogy and paragenesis: No sulphides are observed in the sample. Minor hematite has formed as a product of the alteration.

Mineral Mode: Approximate modal proportions are: K-feldspar 60%, quartz 25%, sericite 7%, albite 5%, hematite 2% and traces of zircon, apatite and leucoxene.

Interpretation and Comments: It is interpreted that the sample represents an altered, moderately porphyritic biotite-pyroxene dacite, probably emplaced as a lava and having weak relict flow foliation. The rock contained phenocrysts of plagioclase, plus a few of biotite, along with microphenocrysts of FeTi oxide and possible pyroxene in a fine grained

(aphanitic/glassy) quartzofeldspathic groundmass. Pervasive strong alteration has led to replacement of the rock by K-feldspar, quartz, sericite and minor hematite. The alteration may be due to low grade metamorphic effects and is of potassic-phyllic type, occurring under oxidising conditions.

378149 TS

Summary: Altered porphyritic quartz-biotite-pyroxene latite, perhaps representing a former lava. The rock contained scattered phenocrysts of plagioclase and biotite, with a few glomeroporphyritic aggregates of plagioclase-pyroxene-biotite-FeTi oxide-apatite and a few microphenocrysts of FeTi oxide in a fine grained (perhaps aphanitic) groundmass that was rich in K-feldspar, plus minor quartz, plagioclase and ferromagnesian material. There has been moderate to strong pervasive alteration of propylitic type imposed, with partial replacement of igneous minerals by albite, sericite, chlorite, carbonate and trace leucoxene. A few irregular veins cut the altered rock; they range from quartz-rich, with K-feldspar selvages to carbonate-rich.

Handspecimen: The sample is composed of a massive brown-grey to pink-grey altered porphyritic, fine grained intermediate to felsic igneous rock. It contains scattered tabular feldspar phenocrysts up to 5 mm across and a few smaller chloritic aggregates that might represent former ferromagnesian phenocrysts set in a fine grained feldspathic groundmass. Staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant in the groundmass. The sample contains minor magnetite as it is moderately magnetic, with susceptibility up to 770×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. There are scattered, variably altered tabular phenocrysts of plagioclase up to 3 mm across and less common smaller phenocrysts of biotite up to 1 mm across. There are also a few microphenocrysts of FeTi oxide (e.g. titanomagnetite) and a few glomeroporphyritic aggregates up to several millimetres across that are composed of plagioclase-altered ferromagnesian phase-biotite-FeTi oxide-trace apatite and zircon. Relict shapes suggest that the altered ferromagnesian phase was a pyroxene. The phenocrystal phases occur in an altered and partly recrystallised fine grained (maybe originally aphanitic) feldspathic groundmass - rich in K-feldspar, but with minor plagioclase, quartz, ferromagnesian material and trace FeTi oxide. From the relict texture and interpreted primary mineralogy, the rock is considered to represent a porphyritic quartz-biotite-pyroxene latite, perhaps emplaced as a lava.

b) Alteration and structure: The rock has undergone moderate to strong pervasive alteration and minor veining. There has been partial replacement of plagioclase by albite, sericite and carbonate. Most biotite has been replaced by chlorite \pm sericite \pm leucoxene, although minor relict biotite occurs. All former pyroxene has been replaced by carbonate \pm chlorite and igneous FeTi oxide is locally altered to leucoxene. The groundmass has been patchily recrystallised to fine to medium grained inequigranular K-feldspar, but there are considerable less recrystallised and interstitial zones rich in fine grained K-feldspar, albite, sericite, chlorite, carbonate and trace hematite. The altered rock has been cut by a few irregular veins up to 0.4 mm across. Some are quartz-rich, with thin alteration selvages of K-feldspar, sericite and chlorite, whereas other veins are carbonate-rich. The alteration assemblage is considered to be largely of propylitic type.

c) Mineragraphy and paragenesis: No sulphides are observed in the sample. The rock contains a little relict igneous FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: K-feldspar 35%, plagioclase (including albite) 25%, sericite 15%, chlorite 10%, carbonate 8%, quartz 5%, FeTi oxide 1% and traces of zircon, apatite, hematite, biotite and leucoxene.

Interpretation and Comments: It is interpreted that the sample represents a porphyritic quartz-biotite-pyroxene latite, perhaps emplaced as a lava. The rock contained scattered phenocrysts of plagioclase and biotite, with a few glomeroporphyritic aggregates of plagioclase-pyroxene-biotite-FeTi oxide-apatite and a few microphenocrysts of FeTi oxide in

a fine grained (perhaps aphanitic) groundmass that was rich in K-feldspar, plus minor quartz, plagioclase and ferromagnesian material. There has been moderate to strong pervasive alteration of propylitic type imposed, with partial replacement of igneous minerals by albite, sericite, chlorite, carbonate and trace leucoxene. A few irregular veins cut the altered rock; they range from quartz-rich, with K-feldspar selvages to carbonate-rich.

378150 TS

Summary: Medium grained lithic-feldspathic-quartz sandstone, with a mixed felsic to intermediate volcanic and sedimentary provenance. Lithic grains include volcanic material as well as fine grained siliceous and sericitic sedimentary material. The rock has undergone pervasive strong alteration under oxidising conditions to develop an assemblage of albite, quartz, carbonate (e.g. dolomite), sericite and hematite.

Handspecimen: The sample is composed of a massive to weakly foliated, pink-brown, medium to coarse grained sandstone. It has a well preserved relict detrital grain texture, with individual grains up to 2-3 mm across. There may be considerable carbonate interstitial to the detrital grains plus minor hematite pigmentation. Testing of the section offcut with dilute HCl gave little reaction, indicating that the carbonate may be dolomite or ankerite. Likewise, testing with sodium cobaltinitrite did not indicate the presence of K-feldspar. The sample is very weakly magnetic, with susceptibility up to 25×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the rock has a moderately well preserved relict detrital grain texture, with abundant tightly packed detrital grains and only a small matrix component. Detrital grains are angular to sub-rounded and are dominated by lithics, altered plagioclase and quartz. Grains of plagioclase and quartz are up to 1 mm across, with probable derivation from a volcanic source. Lithic grains are up to 2 mm across and include a large component of volcanic-derived grains (generally fine grained, locally porphyritic and possibly pumiceous material of felsic to intermediate volcanic composition). There is also a component of lithic grains that are interpreted as sedimentary (or metasedimentary) in origin. These range from polycrystalline quartz-rich aggregates (e.g. metachert, siltstone) to sericite-quartz (perhaps shaly material). In addition, there are a few detrital flakes of muscovite up to 1 mm across along with altered FeTi oxide and a trace of zircon. The minor matrix component may have been muddy to silty material and probably of volcanoclastic derivation. The relict textures indicate that the rock is a lithic-feldspathic-quartz sandstone, with a mixed volcanic and sedimentary provenance.

b) Alteration and structure: The sandstone has undergone strong pervasive alteration, maybe as a result of very low grade metamorphism. Detrital plagioclase has been albitised and also locally replaced by carbonate and sericite. Lithic grains and finer matrix material have been replaced by finely granular albite and minor quartz, in places accompanied by sericite, carbonate, hematite and traces of chlorite. There has been rather abundant growth of irregular porphyroblastic masses of carbonate throughout. Hematite has locally largely replaced lithic grains as well as former detrital FeTi oxide and hematite also occurs as a fine dusting throughout. Weak deformation effects on the rock are indicated by slight development of preferred orientation in sericite masses at detrital grain boundaries and in lithic grains. The alteration assemblage of albite-quartz-carbonate-sericite-hematite (-chlorite) is viewed as having propylitic affinities and occurring under oxidising conditions. Subsequent minor supergene alteration effects have caused local replacement of carbonate by goethite.

c) Mineragraphy and paragenesis: No sulphides are observed in the sample. Minor hematite has formed as a product of the alteration.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 55%, quartz 25%, carbonate (dolomite/ankerite) 14%, sericite/muscovite 3%, hematite 2% and traces of zircon, chlorite and goethite.

Interpretation and Comments: It is interpreted that the sample is a medium grained lithic-feldspathic-quartz sandstone, with a mixed felsic to intermediate volcanic and sedimentary provenance. Lithic grains include volcanic material as well as fine grained siliceous and sericitic sedimentary material. The rock has undergone pervasive strong alteration of

propylitic type under oxidising conditions to develop an assemblage of albite, quartz, carbonate (e.g. dolomite), sericite, hematite and trace chlorite.

378151 TS

Summary: Medium to coarse grained lithic-crystal tuff, probably of intermediate to felsic composition. The rock has abundant angular volcanic lithic fragments as well as a population of altered plagioclase grains, a small amount of altered ferromagnesian and FeTi oxide material, all enclosed in a fine grained, altered and recrystallised volcanoclastic matrix, probably originally composed of fine ash. Volcanic fragments are fine grained, commonly sparsely porphyritic, with some having perlitic cracking texture and pumiceous texture. Many volcanic fragments contain fine grained K-feldspar, but much of the rock (matrix, fragments and plagioclase grains) has been replaced by fine grained (and locally medium grained) albite, along with minor chlorite, a little quartz, sericite and traces of epidote, leucoxene and hematite.

Handspecimen: The sample is composed of a coarse grained volcanoclastic rock. It contains abundant irregular to sub-rounded fragments of fine grained altered porphyritic volcanic rock up to 1.5 cm across. Most of these are brick red-pink in colour although a few are grey-green and they are enclosed in a pink-grey-green matrix. The fragments commonly contain a few altered feldspar phenocrysts. Fragments are largely matrix supported, with matrix being composed of finer grained volcanoclastic material and isolated feldspar grains. Chlorite alteration is evident in the matrix. Some of the fragments contain abundant K-feldspar, as indicated by staining of the section offcut with sodium cobaltinitrite, but some fragments and the matrix, have little K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the rock has a moderately preserved relict medium to coarse grained fragmental texture. There is a population of irregular shaped volcanic fragments up to 1 cm across as well as scattered altered plagioclase grains up to 2 mm across, along with a few small altered ferromagnesian grains, traces of altered FeTi oxide and traces of relict apatite and zircon. Volcanic fragments are commonly fine grained, with many being sparsely porphyritic (plagioclase phenocrysts); however, some fragments display former glassy texture (perlitic cracking) and some were evidently pumiceous. The matrix hosting the fragments and altered plagioclase grains is composed of fine grained volcanoclastic material, perhaps representing former pumiceous ash. From the relict textures and inferred primary mineralogy of the rock, it is considered that the sample represents an altered, medium to coarse grained lithic-crystal tuff, probably of intermediate to felsic composition.

b) Alteration and structure: The original volcanoclastic rock has undergone rather strong and pervasive alteration, due to either or both very low grade metamorphism or hydrothermal action. Many of the volcanic fragments have had their fine grained groundmass material replaced by K-feldspar, but others are replaced largely by albite, along with minor chlorite, quartz and sericite. Matrix material has been dominantly replaced by albite (mostly fine grained but in places slightly coarser), along with patchy chlorite and minor quartz, K-feldspar and trace sericite and leucoxene. Former plagioclase grains have been largely albitised, but in places there is minor development of epidote and sericite. Former ferromagnesian grains have been replaced by chlorite \pm leucoxene \pm epidote, and FeTi oxide by leucoxene. Both the matrix and the fragments are locally dusted by fine grained hematite. The alteration in the sample is dominantly of sodic type, but with some gradation into propylitic and potassic types.

c) Mineragraphy and paragenesis: No sulphides are observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (mostly albite) 70%, K-feldspar 15%, chlorite 8%, quartz 5%, sericite 1% and traces of epidote, hematite, zircon, apatite and leucoxene.

Interpretation and Comments: It is interpreted that the sample is a medium to coarse grained lithic-crystal tuff, probably of intermediate to felsic composition. The rock has abundant angular volcanic lithic fragments as well as a population of altered plagioclase grains, a small amount of altered ferromagnesian and FeTi oxide material, all enclosed in a fine grained, altered and recrystallised volcanoclastic matrix, probably originally composed of fine ash. Volcanic fragments are fine grained, commonly sparsely porphyritic, with some having perlitic cracking texture and pumiceous texture. Many volcanic fragments contain fine grained K-feldspar, but much of the rock (matrix, fragments and plagioclase grains) has been replaced by fine grained (and locally medium grained) albite, along with minor chlorite, a little quartz, sericite and traces of epidote, leucoxene and hematite.

378152 TS

Summary: Coarse grained lithic-crystal tuff, grading to volcanic breccia. The rock is probably of felsic composition and contains abundant lithic fragments that include former glassy, pumiceous and porphyritic material. There is also a smaller population of mineral grains (mainly plagioclase, with minor quartz and altered ferromagnesian and FeTi oxide grains), all hosted in an altered and finely recrystallised matrix, perhaps originally composed of fine ashy pumiceous material. The rock has undergone feldspathic alteration, with replacement of many volcanic fragments by fine grained K-feldspar, or by albite \pm quartz \pm chlorite \pm sericite. Matrix material has been finely recrystallised into dominant albite \pm quartz \pm sericite.

Handspecimen: The sample is composed of an altered coarse grained felsic tuff, grading to volcanic breccia. It contains abundant white, pink and pale grey angular fragments up to 1.5 cm across and a smaller population of feldspar grains set in a fine grained grey quartzofeldspathic matrix. The matrix locally contains a few dark chloritic patches. Staining of the section offcut with sodium cobaltinitrite, showed that many fragments contain abundant K-feldspar, but other fragments and the matrix have little K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict coarse grained fragmental texture is moderately well preserved. The rock represents a lithic-crystal tuff, grading to volcanic breccia, with abundant angular to sub-rounded lithic fragments up to 1 cm across and scattered discrete mineral grains up to 1.5 mm across. The latter are mostly altered plagioclase, but there are a few quartz grains and traces of altered ferromagnesian grains and FeTi oxide. Lithic fragments are all of volcanic origin and are probably of felsic composition. They include former glassy material (with relict perlitic cracking), pumiceous material, and rather abundant fine grained (aphanitic) porphyritic volcanic rock (with plagioclase phenocrysts set in a quartzofeldspathic groundmass). Lithic fragments and mineral grains occur in a fine grained, altered and recrystallised matrix that comprises about 30 % of the sample. The matrix may have been composed of fine grained ashy/pumiceous material. The bulk composition of the sample suggests that it is of felsic volcanic composition.

b) Alteration and structure: The original fragmental rock has undergone rather strong and pervasive alteration, due to either or both very low grade metamorphism or hydrothermal action. Many of the volcanic fragments have had their fine grained groundmass material replaced by K-feldspar, but others are replaced largely by albite, along with minor chlorite, quartz and sericite. Matrix material has been dominantly replaced by albite (mostly fine grained but in places slightly coarser), along with patchy sericite, chlorite and minor quartz, K-feldspar and traces of leucoxene. Plagioclase grains have been largely albitised, as well as being locally flecked by sericite. Former ferromagnesian grains have been replaced by chlorite \pm leucoxene \pm sericite, and FeTi oxide by leucoxene. The alteration in the sample is largely feldspathic in character, with many fragments having potassic alteration, but the remainder of the rock dominated by sodic alteration. The rock locally shows effects of weathering, with goethite staining (especially of chlorite and sericite aggregates) and local goethite aggregates,

c) Mineragraphy and paragenesis: No sulphides are observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (mostly albite) 60%, K-feldspar 20%, quartz 12%, sericite 5%, chlorite 2%, goethite 1% and a trace of leucoxene.

Interpretation and Comments: It is interpreted that the sample is a coarse grained lithic-crystal tuff, grading to volcanic breccia and probably of felsic volcanic composition. It contains abundant lithic fragments that include former glassy, pumiceous and porphyritic material and there are discrete mineral grains (mainly plagioclase, with minor quartz and altered ferromagnesian and FeTi oxide grains), all hosted in an altered and finely recrystallised matrix, perhaps originally composed of fine ashy pumiceous material. The rock

has undergone feldspathic alteration (sodic > potassic), with replacement of many volcanic fragments by fine grained K-feldspar, or by albite \pm quartz \pm chlorite \pm sericite. Matrix material has been finely recrystallised into dominant albite \pm quartz \pm sericite.

378153 TS

Summary: Medium grained lithic-crystal tuff or epiclastic sandstone, with a mostly felsic volcanic provenance (but with a small contribution from a siliceous metamorphic source). Lithic grains are dominated by former pumiceous material, but there is a small population of fine grained quartz-rich and quartz-muscovite grains. Mineral grains are dominated by altered plagioclase and quartz, with a few muscovite flakes. Pervasive strong alteration has been imposed, with total replacement of pumiceous material by fine grained K-feldspar, plus subordinate chlorite, minor carbonate and quartz. Plagioclase has been albitised and also flecked by sericite. Alteration is considered to be of transitional potassic-propylitic type.

Handspecimen: The sample is composed of a massive, medium grained, dark brownish-grey sandstone or tuff. The rock contains abundant small lithic, feldspar and quartz grains and slight weathering effects have led to the formation of minor goethite staining and spotting. Staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant throughout. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital/fragmental texture is moderately preserved. There are abundant angular, but rather diffuse, fragments up to 2 mm across that are interpreted to represent altered pumiceous material. Some have relict frothy texture and all are tightly packed. There are other small lithic grains, generally being fine grained polycrystalline quartz aggregates, but also a few quartz-muscovite aggregates. The rock also has abundant detrital mineral grains up to 0.6 mm across. Many appear to be former volcanic phenocrysts and include altered plagioclase and quartz. However, there are also scattered small muscovite flakes and rare FeTi oxide and zircon grains. From the relict texture, it is inferred that the rock represents a lithic-crystal tuff of felsic composition, or a closely related epiclastic sandstone. Most of the detrital material has come from a felsic volcanic source, but there is also a smaller source from siliceous metamorphic material.

b) Alteration and structure: The original volcanoclastic rock has undergone strong and pervasive alteration, due to either or both very low grade metamorphism or hydrothermal action. All pumiceous material is altered, mostly to a fine grained assemblage dominated by K-feldspar, but with subordinate chlorite, minor quartz and traces of sericite and rutile/leucoxene. However, some pumiceous grains are chloritised. Throughout the altered pumiceous material, there has been growth of disseminated grains of porphyroblastic carbonate up to 0.3 mm across. It is interpreted that the carbonate is an Fe-bearing type, e.g. ankerite or siderite. Original plagioclase grains have been albitised and also flecked lightly by sericite. The alteration is considered to be transitional between potassic and propylitic type. Weathering effects have been subsequently imposed, with considerable replacement of carbonate by goethite.

c) Mineralogy and paragenesis: No sulphides are observed in the sample.

Mineral Mode: Approximate modal proportions are: K-feldspar 50%, plagioclase (albite) 20%, quartz and chlorite each 10%, sericite/muscovite and goethite each 2% and traces of FeTi oxide, zircon and leucoxene/rutile.

Interpretation and Comments: It is interpreted that the sample is a medium grained lithic-crystal tuff or epiclastic sandstone, with a dominant felsic volcanic provenance, but with a small contribution from a siliceous metamorphic source. Lithic grains are dominated by former pumiceous material, but there is a small population of fine grained quartz-rich and quartz-muscovite grains. Mineral grains are dominated by altered plagioclase and quartz, with a few muscovite flakes. Pervasive strong alteration has been imposed, with total replacement of pumiceous material by fine grained K-feldspar, plus subordinate chlorite, minor carbonate and quartz. Plagioclase has been albitised and also flecked by sericite. Alteration is considered to be of transitional potassic-propylitic type.

378154 TS

Summary: Moderately altered, porphyritic and slightly flow foliated felsic volcanic rock, probably representing a lava of rhyodacite composition. The rock contains scattered partly altered phenocrysts of plagioclase and pseudomorphs after a few microphenocrysts of ferromagnesian material and FeTi oxide, set in a partly recrystallised, fine grained groundmass dominated by K-feldspar and plagioclase. The rock has undergone moderate alteration to a propylitic assemblage of albite, with minor chlorite, carbonate and sericite, and the emplacement of several elongate veinlike aggregates (perhaps co-planar with flow foliation) of quartz \pm chlorite.

Handspecimen: The sample is composed of a pinkish-brown, fine grained, altered porphyritic felsic volcanic. It contains scattered feldspar phenocrysts up to 3-4 mm across set in a fine grained, possibly flow foliated, quartzofeldspathic groundmass. Staining of the section with sodium cobaltinitrite showed that K-feldspar is abundant in the groundmass. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. The rock contains scattered, partly altered, tabular phenocrysts of plagioclase up to 3.5 mm long and there are a few pseudomorphs after former ferromagnesian microphenocrysts (perhaps pyroxene, judging by relict grain shape) and a trace of FeTi oxide and relict zircon. Fine grained groundmass constitutes about 80 volume % of the rock. Although it is partly recrystallised, it was evidently slightly flow foliated and had vague sub-trachytic texture. It was dominated by K-feldspar, with small laths of plagioclase and a little quartz and ferromagnesian material. From the relict texture and interpreted primary mineralogy, the sample is considered to be an altered porphyritic felsic volcanic, most likely to lava of rhyodacite composition.

b) Alteration and structure: The volcanic rock has sustained moderate alteration, probably due to very low grade metamorphism. There has been partial albitisation of plagioclase and its flecking by sericite and local carbonate aggregates. Former ferromagnesian grains have been replaced by aggregates of chlorite \pm carbonate \pm rutile, whereas FeTi oxide has been replaced by rutile \pm chlorite. A few irregular porphyroblastic aggregates of carbonate up to 0.5 mm across occur in the groundmass, which has also partly recrystallised to an assemblage of K-feldspar, albite and a little quartz and chlorite. Alteration carbonate in the sample is likely to be of ankeritic to sideritic composition. The rock contains several elongate, veinlike aggregates of medium grained quartz \pm a little chlorite, up to 0.5 mm wide. These aggregates are sub-parallel and may have developed co-planar with the pre-existing flow foliation. Alteration is interpreted to be of propylitic type. The rock has undergone slight weathering effects that have led to slight goethite staining and formation of a few small goethite masses.

c) Mineragraphy and paragenesis: No sulphides are observed in the sample.

Mineral Mode: Approximate modal proportions are: K-feldspar 40%, plagioclase (including albite) 35%, quartz 15%, carbonate 4%, chlorite 3%, sericite 2% and traces of rutile, zircon and goethite.

Interpretation and Comments: It is interpreted that the sample represents a moderately altered, porphyritic and slightly flow foliated felsic volcanic rock, e.g. a lava of rhyodacite composition. The rock contains scattered partly altered phenocrysts of plagioclase and pseudomorphs after a few microphenocrysts of ferromagnesian material and FeTi oxide, set in a partly recrystallised, fine grained groundmass dominated by K-feldspar and plagioclase. The rock has undergone moderate alteration to a propylitic assemblage of albite, with minor chlorite, carbonate and sericite, and the emplacement of several elongate veinlike aggregates (perhaps co-planar with flow foliation) of quartz \pm chlorite.

378155 TS

Summary: Altered porphyritic and amygdaloidal rhyodacite or quartz latite. The original rock contained scattered phenocrysts of plagioclase and minor ferromagnesian material, along with amygdules, set in a fine grained groundmass rich in K-feldspar, quartz and plagioclase. The rock has undergone strong pervasive propylitic alteration, with development of albite, sericite, carbonate (dolomite) and a little chlorite and rutile. Amygdules are filled by quartz, with minor carbonate, sericite and chlorite. A few thin sub-planar quartz-rich veins cut the altered rock.

Handspecimen: The sample is composed of a massive, moderately porphyritic, fine grained, grey-brown felsic to intermediate igneous rock. It contains scattered altered feldspar phenocrysts along with ovoid amygdules up to 3-4 mm across. Alteration appears to have formed pale brown carbonate and minor chlorite in the sample, with amygdules and rare thin sub-planar veins containing dominant quartz. Staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant in the groundmass. Testing with dilute HCl gave little reaction, indicating that the carbonate may be dolomite. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic and amygdular texture is well preserved despite moderate to strong pervasive alteration. The rock contains scattered altered tabular phenocrysts of plagioclase up to 3.5 mm long and pseudomorphs after uncommon small phenocrysts that are interpreted to have been ferromagnesian phases. Microphenocrysts of FeTi oxide are scattered. The phenocryst phases occur in a fine grained holocrystalline groundmass composed largely of intergrown K-feldspar, with subordinate quartz and plagioclase and traces of finely disseminated FeTi oxide, zircon and apatite. Scattered ovoid to spheroidal amygdules up to 3.5 mm across occur throughout. The relict texture and inferred primary mineralogy imply that the rock was a porphyritic and amygdaloidal rhyodacite or quartz latite.

b) Alteration and structure: The igneous rock has undergone pervasive moderate to strong alteration. All plagioclase has been albitised and also locally replaced by fine grained sericite and carbonate. All ferromagnesian material has been altered to carbonate, with minor sericite and traces of rutile and chlorite. Igneous FeTi oxide has been replaced by rutile. In the groundmass, feldspars are locally replaced by fine grained sericite, carbonate and a little chlorite. Amygdules are filled largely by medium grained quartz, but in places there are aggregates of carbonate, sericite and a little chlorite. The altered rock has been cut by a couple of thin (<0.3 mm), sub-planar extensional veins that are dominated by quartz, but with local carbonate in places. Slight weathering effects imposed on the sample have led to patchy replacement of carbonate by goethite. The alteration assemblage observed is consistent with propylitic type.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 35%, K-feldspar 25%, quartz 20%, sericite 10%, carbonate (dolomite) 6%, chlorite 2%, goethite 1% and traces of rutile, zircon and apatite.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic and amygdaloidal rhyodacite or quartz latite. It may have been emplaced as a shallow intrusive or as a lava. The original rock contained phenocrysts of plagioclase and a possible ferromagnesian phase, set in a fine grained groundmass dominated by K-feldspar, quartz and plagioclase. The rock has undergone pervasive propylitic alteration to albite and sericite, with minor carbonate (dolomite) and a little chlorite and rutile. Amygdules are dominated by quartz, as are uncommon thin sub-planar veins.

378156 TS

Summary: Altered porphyritic and possibly spheroidal felsic volcanic rock, probably representing a former lava. The rock contained scattered tabular plagioclase phenocrysts and uncommon ferromagnesian microphenocrysts in an originally fine grained/glassy quartzofeldspathic groundmass. Alteration and recrystallisation of the groundmass has led to the formation of scattered irregular to ovoid and spheroidal aggregates of quartz and K-feldspar. Elsewhere, the rock has been replaced by albite, K-feldspar, chlorite and minor sericite, with development of a few thin veins that are rich in sericite or in quartz.

Handspecimen: The sample is composed of a relatively massive, speckled grey-green-pink altered fine grained porphyritic felsic igneous rock. There are scattered tabular feldspar phenocrysts up to 3 mm across in a fine grained quartzofeldspathic groundmass that appears to be slightly flow foliated. The rock may have some alteration to chlorite and staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant in the groundmass. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved and there is also possible relict spherulitic texture. The rock retains altered tabular plagioclase phenocrysts up to 3 mm across (with rare tiny apatite inclusions) and rare ferromagnesian microphenocrysts set in an altered and recrystallised groundmass that was originally fine grained (maybe glassy) and of quartzofeldspathic composition, with minor ferromagnesian material and traces of FeTi oxide and zircon. In places, groundmass material has recrystallised to irregular to ovoid and possibly spheroidal aggregates of quartz \pm K-feldspar \pm chlorite. The larger aggregates are up to 5 mm across and could represent devitrification spheroids. The bulk composition of the samples suggests that it represents a felsic volcanic, probably a lava.

b) Alteration and structure: There has been considerable alteration and recrystallisation of the original groundmass. In addition, plagioclase phenocrysts have been replaced by albite and minor sericite, ferromagnesian material by chlorite \pm sericite \pm leucoxene and FeTi oxide by leucoxene. The groundmass has been replaced dominantly by fine grained K-feldspar, with minor albite, quartz, chlorite, sericite and trace leucoxene. However, there are scattered irregular to ovoid and spheroidal aggregates of fine to medium grained quartz \pm K-feldspar \pm chlorite that might represent devitrification structures (possible spheroids). The altered rock has been cut by a fine network of thin, anastomosing sericite veins and in turn these have been cut by rare sub-planar veins up to 0.1 mm wide of quartz \pm sericite. The alteration assemblage is viewed as being transitional between potassic and propylitic types.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: K-feldspar 45%, quartz 25%, plagioclase (albite) 15%, chlorite 9%, sericite 5% and traces of leucoxene, zircon and apatite.

Interpretation and Comments: It is interpreted that the sample represents a former porphyritic and possibly spheroidal felsic volcanic rock, probably a lava. The rock contained scattered tabular plagioclase phenocrysts and uncommon ferromagnesian microphenocrysts in an originally fine grained/glassy quartzofeldspathic groundmass. Strong alteration and recrystallisation of the groundmass has led to the formation of scattered irregular to ovoid and spheroidal aggregates of quartz and K-feldspar. Elsewhere, the rock has been replaced by albite, K-feldspar, chlorite and minor sericite, with development of a few thin veins that are rich in sericite or in quartz. Alteration is considered to be transitional between potassic and propylitic in type.

378157 TS

Summary: Altered porphyritic quartz latite maybe representing a shallow intrusive or less likely, a lava. The original rock contained scattered phenocrysts of plagioclase and a few microphenocrysts of ferromagnesian material and quartz in a holocrystalline, fine to medium grained groundmass of plagioclase, K-feldspar, minor altered ferromagnesian material, quartz and FeTi oxide. The rock contains a few glomeroporphyritic aggregates (?micro-enclaves) of plagioclase-altered ferromagnesian material-FeTi oxide and quartz. There has been pervasive propylitic alteration, probably the result of very low grade metamorphism, with partial replacement by albite, chlorite, sericite and carbonate.

Handspecimen: The sample is composed of a massive, dark grey porphyritic fine grained igneous rock, perhaps of intermediate composition. It contains scattered feldspar phenocrysts up to 2-3 mm across in a fine grained feldspathic groundmass, but which also contains significant chloritised ferromagnesian material. Staining of the section offcut with sodium cobaltinitrite showed that the groundmass contains abundant K-feldspar. The sample contains minor magnetite and is moderately to strongly magnetic, with susceptibility up to 1500×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. There are scattered partly altered tabular plagioclase phenocrysts up to 1.5 mm across and a few microphenocrysts of quartz and pseudomorphs after former ferromagnesian material. The larger grains occur in a holocrystalline, fine to medium grained groundmass (maximum grainsize 0.3 mm) of small plagioclase laths, K-feldspar, minor interstitial quartz and altered ferromagnesian material and a little disseminated FeTi oxide (e.g. titanomagnetite). There are several glomeroporphyritic aggregates (maybe micro-enclaves) up to 1 cm across of medium grained plagioclase-altered ferromagnesian-FeTi oxide-quartz. The relict texture and interpreted primary mineralogy indicate that the rock represents a porphyritic quartz latite, maybe emplaced as a shallow intrusive and less likely as a lava.

b) Alteration and structure: The igneous rock has undergone pervasive moderate to strong alteration, maybe due to very low grade metamorphism. Plagioclase has been partly altered to albite and minor amounts of sericite, carbonate and chlorite. K-feldspar has also been flecked by sericite, chlorite and carbonate. All former ferromagnesian material has been altered to chlorite, carbonate and trace leucoxene, and igneous FeTi oxide has been slightly altered to leucoxene. The rock contains a few alteration patches up to 2 mm across of medium grained chlorite-carbonate-quartz, a single thin stylolitic veinlike aggregate of leucoxene, with a little chlorite and trace pyrite, as well as a few thin shear veins containing chlorite \pm sericite. The alteration assemblage is consistent with propylitic type.

c) Mineragraphy and paragenesis: The sample contains minor relict igneous FeTi oxide (titanomagnetite) as well as a trace of pyrite as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: plagioclase (including albite) 40%, K-feldspar 30%, chlorite 13%, quartz 8%, sericite 5%, carbonate and FeTi oxide each 2% and traces leucoxene and pyrite.

Interpretation and Comments: It is interpreted that the sample is a porphyritic quartz latite with moderate to strong propylitic alteration, perhaps caused by very low grade metamorphism. The original igneous rock may have been emplaced as a shallow intrusive or less likely, a lava. It contained scattered phenocrysts of plagioclase and a few microphenocrysts of ferromagnesian material and quartz in a holocrystalline, fine to medium grained groundmass of plagioclase, K-feldspar, minor altered ferromagnesian material, quartz and FeTi oxide. The rock contains a few glomeroporphyritic aggregates (?micro-

enclaves) of plagioclase-altered ferromagnesian material-FeTi oxide and quartz. Alteration has led to partial replacement of igneous minerals by albite, chlorite, sericite and carbonate.

378158 TS

Summary: Porphyritic quartz micromonzonite, with scattered small plagioclase phenocrysts set in a fine to medium grained groundmass of plagioclase, K-feldspar, altered ferromagnesian material, minor quartz and FeTi oxide. Pervasive strong propylitic alteration has been imposed, with partial replacement by albite and chlorite, plus minor carbonate and hematite.

Handspecimen: The sample is composed of a massive, fine to medium grained, weakly porphyritic intermediate igneous rock. It is brown-grey in colour although the groundmass has a pinkish tinge. There are scattered feldspar phenocrysts up to 2 mm across as well as small dark greenish altered ferromagnesian grains up to 1-2 mm across. The latter appear to have been chloritised. Staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant in the groundmass. The sample contains minor magnetite and is moderately magnetic, with susceptibility up to 740×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. The rock contains scattered altered tabular phenocrysts of plagioclase up to 1.5 mm long and they are set in a fine to medium grained, holocrystalline groundmass of smaller plagioclase laths, rather abundant small grains of K-feldspar, altered ferromagnesian material, minor quartz, forming interstitial masses up to 1 mm across and a little disseminated FeTi oxide (e.g. titanomagnetite). Relict shapes in some of the altered ferromagnesian material suggest that at least some represents former pyroxene grains. Relict textures and inferred primary mineralogy of the rock indicate that it represents an altered porphyritic quartz micromonzonite.

b) Alteration and structure: The original igneous rock has undergone pervasive strong alteration of propylitic type, perhaps as a result of very low grade metamorphism. All plagioclase has been albitised and also locally replaced by fine grained chlorite and carbonate. K-feldspar is slightly altered to carbonate and also lightly dusted by fine grained hematite. All ferromagnesian material has been replaced by chlorite, with a little carbonate and traces of leucoxene. Igneous FeTi oxide is partly altered to hematite. The groundmass contains one or two porphyroblastic alteration masses of carbonate up to 1.5 mm across.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. The rock retains minor igneous FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 50%, K-feldspar 30%, chlorite 10%, quartz 5%, carbonate 3%, FeTi oxide and hematite each 1% and a trace of leucoxene.

Interpretation and Comments: It is interpreted that the sample represents an altered porphyritic quartz micromonzonite. It contained scattered small plagioclase phenocrysts set in a fine to medium grained groundmass of plagioclase, K-feldspar, altered ferromagnesian material, minor quartz and FeTi oxide. Pervasive strong propylitic alteration has been imposed, with partial replacement by albite and chlorite, plus minor carbonate and hematite.

378159 TS

Summary: Altered porphyritic quartz monzonite. The original igneous rock contained abundant tabular plagioclase phenocrysts, with interstitial medium grained K-feldspar, ferromagnesian material and minor quartz, plagioclase and FeTi oxide (titanomagnetite). There has been moderate to strong imposed alteration of propylitic type. This has led to replacement of some of the primary minerals by albite and chlorite, with minor carbonate, sericite and epidote, plus traces of titanite and leucoxene.

Handspecimen: The sample is composed of a massive, medium to coarse grained, slightly porphyritic, intermediate igneous rock. It is mostly dark green-grey in colour, but contains minor pink feldspar. The rock is rich in feldspars and altered ferromagnesian minerals, with the latter having been replaced by chlorite. Staining of the section offcut with sodium cobaltinitrite showed that there is a moderate amount of K-feldspar, interstitial to dominant plagioclase. The rock contains minor disseminated magnetite as it is moderately to strongly magnetic, with susceptibility of up to 1300×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. The rock contains abundant altered tabular phenocrysts of plagioclase up to 4 mm across, with interstitial medium grained K-feldspar, altered ferromagnesian material, minor plagioclase, quartz, disseminated FeTi oxide (e.g. titanomagnetite) and a trace of apatite. K-feldspar and quartz grains are up to 1 mm across and FeTi oxide grains up to 0.5 mm across. There are no diagnostic shapes recognisable in the altered ferromagnesian material. The relict texture and interpreted primary mineralogy indicates that the rock represents a former porphyritic quartz monzonite.

b) Alteration and structure: The igneous rock has undergone pervasive moderate to strong alteration of propylitic type, perhaps as a result of hydrothermal and/or very low grade metamorphic processes. All plagioclase has been albitised and also locally replaced by fine grained sericite, epidote, chlorite and carbonate. In contrast, K-feldspar is rather fresh, with only slight alteration to carbonate. All ferromagnesian material has been altered to chlorite \pm carbonate \pm titanite \pm leucoxene. In places, there has been development of a weak network of thin irregular chlorite veins and there is a trace of finely dispersed hematite.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample, but there is disseminated relict igneous titanomagnetite.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 55%, K-feldspar 20%, chlorite 10%, quartz 5%, sericite and carbonate each 3%, FeTi oxide (titanomagnetite) 2%, epidote 1% and traces of hematite, titanite, leucoxene and apatite.

Interpretation and Comments: It is interpreted that the sample represents an altered porphyritic quartz monzonite. The rock has undergone pervasive propylitic alteration that has developed albite and chlorite, with minor carbonate, sericite and epidote. The original rock has plagioclase phenocrysts and interstitial medium grained K-feldspar and ferromagnesian material, plus minor plagioclase, quartz and FeTi oxide.

378160 TS

Summary: Porphyritic and possibly amygdaloidal quartz latite, with moderate to strong propylitic alteration. The original igneous rock contained scattered phenocrysts of plagioclase and probably pyroxene in a fine grained, holocrystalline groundmass dominated by K-feldspar, but with minor plagioclase, quartz and ferromagnesian material. There are a few glomeroporphyritic aggregates of former plagioclase, pyroxene, FeTi oxide and apatite and in the groundmass, several aggregates that might represent amygdules. There has been total replacement of igneous plagioclase, pyroxene and FeTi oxide by an assemblage of albite, chlorite and carbonate, with a little sericite, leucoxene, hematite and pyrite. Amygdules are filled by carbonate, in places with accompanying quartz and a little sericite.

Handspecimen: The sample is composed of a massive, grey, porphyritic fine grained intermediate igneous rock. In places, there are small pink patches as well as small dark greenish aggregates representing altered ferromagnesian grains. The rock contains scattered plagioclase phenocrysts up to 4 mm across and smaller altered ferromagnesian grains in a fine grained feldspathic groundmass. Alteration of ferromagnesian to chlorite has occurred. Staining of the section offcut with sodium cobaltinitrite showed that there is abundant K-feldspar in the groundmass. The rock is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. The rock contains abundant altered tabular phenocrysts of plagioclase up to 3.5 mm across, and less common altered phenocrysts of a ferromagnesian phase up to 3 mm across. Relict shapes of the latter imply that it was formerly pyroxene. There are a few glomeroporphyritic aggregates of plagioclase, pyroxene, FeTi oxide \pm apatite scattered throughout, as well as a few microphenocrysts of FeTi oxide. The phenocryst phases occur in a fine grained holocrystalline groundmass that is dominated by K-feldspar, although there is a minor amount of plagioclase, quartz and altered ferromagnesian material. Several irregular to ovoid masses of carbonate \pm quartz \pm sericite up to 5 mm across occur in the groundmass and could represent amygdules. The relict textures and inferred primary mineralogy indicate that the rock is a porphyritic and amygdaloidal quartz latite.

b) Alteration and structure: There has been moderate to strong and pervasive propylitic alteration imposed. All plagioclase has been albitised and also lightly flecked by sericite, chlorite and carbonate. All former ferromagnesian material has been replaced by chlorite \pm carbonate \pm leucoxene \pm pyrite and FeTi oxide replaced by leucoxene \pm hematite \pm pyrite. There are scattered aggregates up to 5 mm across of medium grained carbonate \pm quartz \pm sericite that probably represent amygdale fillings and there are a couple of irregular veinlike masses up to 0.5 mm wide of quartz, carbonate and chlorite. The rock has locally been affected by supergene oxidation, with development of a little goethite staining.

c) Mineragraphy and paragenesis: The rock contains a few grains of disseminated pyrite up to 0.3 mm across as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: K-feldspar 40%, plagioclase (albite) 35%, carbonate 8%, chlorite and quartz each 7%, sericite and leucoxene each 1% and traces of apatite, pyrite, hematite and goethite.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic and possibly amygdaloidal quartz latite. The alteration is of propylitic type. The original igneous rock contained scattered phenocrysts of plagioclase and probably pyroxene in a fine grained, holocrystalline groundmass dominated by K-feldspar, but with minor plagioclase, quartz and ferromagnesian material. There are a few glomeroporphyritic aggregates of former plagioclase, pyroxene, FeTi oxide and apatite and in the groundmass, several aggregates that might represent amygdules that contain carbonate \pm quartz \pm sericite. There has been total

replacement of igneous plagioclase, pyroxene and FeTi oxide by an assemblage of albite, chlorite and carbonate, with a little sericite, leucoxene, hematite and pyrite. Uncommon veinlike masses contain quartz, carbonate and chlorite.

378161 TS

Summary: Altered porphyritic quartz micromonzonite, with scattered plagioclase phenocrysts. The rock contains abundant fine to medium grained K-feldspar and quartz, with subordinate amounts of altered ferromagnesian material (originally included biotite). Interstitial K-feldspar and quartz commonly display micrographic intergrowths. The rock has undergone low grade propylitic alteration with partial replacement by albite, chlorite and sericite. Slight weathering effects have led to the formation of goethite staining and aggregates. There is no textural evidence for the rock to be a volcanoclastic sandstone.

Handspecimen: The sample is composed of a massive, fine to medium grained, porphyritic igneous rock. It contains scattered altered feldspar phenocrysts up to 3 mm across and smaller altered ferromagnesian aggregates in a dark pink quartzofeldspathic groundmass. Ferromagnesian material has been altered to chlorite and feldspar phenocrysts are probably partly sericitised. The rock is slightly weathered with patchy goethite development. Staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant. The sample contains minor disseminated magnetite and is moderately to strongly magnetic, with susceptibility of up to 1480×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. There is no textural evidence for the rock to be of clastic origin, e.g. with detrital grains. The rock contains abundant, largely altered, tabular phenocrysts of plagioclase up to 3 mm across. These are intergrown with a fine to medium grained aggregate (typically with a grain size of ≤ 1 mm) of K-feldspar, quartz. Altered ferromagnesian material, plagioclase, a little FeTi oxide (e.g. titanomagnetite) and a trace of apatite. Locally, ferromagnesian material formed glomeroporphyritic aggregates up to 3 mm across, also incorporating FeTi oxide and apatite. Relict shapes suggest some of the ferromagnesian material was biotite, but it is likely that pyroxene and/or hornblende were also originally present. Interstitial to plagioclase phenocrysts, it is common to have intergrowth of K-feldspar and quartz, locally micrographically. The relict texture and interpreted primary mineralogy of the rock indicates that it represents a porphyritic quartz micromonzonite. It was probably emplaced as a shallow intrusive.

b) Alteration and structure: The igneous rock has undergone pervasive moderate to strong alteration and slight weathering effects. Plagioclase has been partly albitised and is also strongly flecked by sericite and minor chlorite. All ferromagnesian material has been replaced by chlorite \pm sericite, with trace leucoxene. Igneous FeTi oxide has been partly altered to hematite, leucoxene and titanite. Interstitial K-feldspar is generally pigmented reddish in colour by fine dusty hematite. Alteration is probably due to very low grade metamorphic effects and is of propylitic type. Subsequent weathering effects have caused development of scattered small aggregates of goethite, along with goethite staining of chlorite \pm sericite at altered ferromagnesian sites.

c) Mineralogy and paragenesis: No sulphides have been observed in the sample. There is disseminated relict FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (includes albite) 35%, K-feldspar 30%, quartz 15%, chlorite 10%, sericite 6%, FeTi oxide (titanomagnetite) 2%, goethite 1% and traces of apatite, hematite, leucoxene and titanite.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic quartz micromonzonite, representing a shallow intrusive. There is no textural evidence that the sample represents a volcanoclastic sandstone, e.g. with a relict detrital grain texture. The rock contains abundant fine to medium grained K-feldspar and quartz, with subordinate amounts of altered ferromagnesian material (originally included biotite). Interstitial K-feldspar and quartz commonly display micrographic intergrowths. The rock has undergone

low grade propylitic alteration with partial replacement by albite, chlorite and sericite. Slight weathering effects have led to the formation of goethite staining and aggregates.

378162 TS

Summary: Altered porphyritic quartz latite, perhaps representing a shallow intrusive. The original rock contained phenocrysts of plagioclase, ferromagnesian material (probably pyroxene) and microphenocrysts of FeTi oxide. There are a few glomeroporphyritic aggregates of the same minerals. The groundmass is fine to medium grained and dominated by plagioclase, K-feldspar and quartz. Strong pervasive alteration of propylitic type has been imposed, maybe as a result of very low grade metamorphism, with replacement of igneous minerals by albite, chlorite plus a little sericite, epidote and leucoxene.

Handspecimen: The sample is composed of a massive, altered, porphyritic intermediate to felsic igneous rock. It contains scattered altered ferromagnesian and feldspar phenocrysts up to several millimetres across in a fine grained, dark mauve-red-grey feldspathic groundmass. Ferromagnesian phenocrysts have been replaced by fine grained aggregates of dark green chlorite. Staining of the section offcut with sodium cobaltinitrite showed that K-feldspar is abundant in the groundmass. The sample contains minor disseminated magnetite and is moderately magnetic, with susceptibility of up to 710×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. The rock contains altered tabular phenocrysts of plagioclase up to 4 mm long, pseudomorphs after former ferromagnesian phenocrysts up to 2 mm long and a few microphenocrysts of FeTi oxide (titanomagnetite). There are also a few glomeroporphyritic aggregates up to several millimetres across that were composed of plagioclase, ferromagnesian grains, FeTi oxide and traces of apatite. Relict shapes suggest that the ferromagnesian phase would have been pyroxene. The phenocrystal phases occur in a fine to medium grained (up to 0.5 mm), holocrystalline groundmass that is dominated by small laths of plagioclase, interstitial turbid, hematite-pigmented K-feldspar and quartz, along with a little altered ferromagnesian material and traces of FeTi oxide. From the relict texture and interpreted primary mineralogy, the rock is considered to be an altered porphyritic quartz latite, maybe emplaced as a shallow intrusive.

b) Alteration and structure: The igneous rock has sustained pervasive strong alteration, probably as a result of very low grade metamorphism. Plagioclase has been albitised and also flecked by sericite, chlorite and epidote. Groundmass K-feldspar remains unaltered except for hematite pigmentation. All former ferromagnesian material has been replaced by chlorite, with a little epidote, sericite and traces of leucoxene. Igneous FeTi oxide has been slightly altered to leucoxene. The observed alteration assemblage is consistent with propylitic type.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There is minor disseminated relict FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 40%, K-feldspar 35%, chlorite 13%, quartz 8%, sericite, epidote and FeTi oxide (titanomagnetite) each 1% and traces of apatite, hematite and leucoxene.

Interpretation and Comments: It is interpreted that the sample represents a porphyritic quartz latite, perhaps emplaced as a shallow intrusive, that has undergone subsequent pervasive strong alteration. The original rock contained phenocrysts of plagioclase, ferromagnesian material (probably pyroxene) and microphenocrysts of FeTi oxide. There are a few glomeroporphyritic aggregates of the same minerals. The groundmass is fine to medium grained and dominated by plagioclase, K-feldspar and quartz. Alteration is of propylitic type and may have resulted from very low grade metamorphism, with replacement of igneous minerals by albite, chlorite plus a little sericite, epidote and leucoxene.

378163 TS

Summary: Medium to coarse grained volcanoclastic sandstone with intermediate to felsic volcanic provenance. The rock contains abundant altered lithic detrital grains (fine grained and locally porphyritic and flow-foliated intermediate volcanic material), plus altered plagioclase grains, quartz and a little detrital muscovite. Detrital components occur in a fine grained quartzofeldspathic matrix. The rock has undergone pervasive propylitic alteration to develop an assemblage of dominant albite, with subordinate quartz and chlorite, minor carbonate, a little sericite and trace rutile and pyrite.

Handspecimen: The sample is composed of a massive, dark grey medium to coarse grained volcanoclastic rock, e.g. tuff or epiclastic sandstone. It contains abundant grains of plagioclase and lithic material up to a few millimetres across in a finer grained dark matrix. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, it is apparent that the rock is a medium to coarse grained volcanoclastic. It contains a moderate to well preserved relict texture, with abundant angular lithic grains up to several millimetres across, plus scattered detrital altered grains of plagioclase up to 2 mm across and smaller and less common grains of quartz, a few small flakes of muscovite and traces of detrital carbonate, FeTi oxide (now altered) and a single small grain of chromite. Lithic grains are dominated by fine grained, locally flow-foliated and porphyritic (plagioclase-phyric) intermediate volcanic rock, but with rare small quartzite grains. Detrital grains dominate, but there is a small interstitial matrix component, composed of smaller detrital grains and finely recrystallised feldspar and quartz. From the relict texture and inferred primary mineralogy, it is interpreted that the rock represents a medium to coarse grained volcanoclastic sandstone, with a dominant intermediate to felsic volcanic provenance. However, the grain of chromite indicates a local ultramafic source of detritus.

b) Alteration and structure: The rock has undergone pervasive moderate to strong alteration. All plagioclase (as detrital discrete grains and as a component of the lithic grains) has been replaced by albite, with local development of carbonate, chlorite and a little sericite. The finer grained matrix component has been replaced by fine grained albite and quartz, with minor chlorite and traces of sericite, carbonate, rutile, pyrite and possible carbonaceous material. The rock contains a few irregular alteration patches up to a few millimetres across composed largely of carbonate and/or chlorite, with local traces of pyrite. It is possible that scattered small aggregates of fine grained metamorphic biotite developed in the rock as a result of alteration (metamorphism), but if so, biotite has subsequently been replaced by fine grained retrograde chlorite. The rock exhibits uncommon irregular discontinuous veinlets of carbonate. The alteration assemblage is consistent with propylitic type, but could simply be the result of very low grade metamorphism.

c) Mineragraphy and paragenesis: A few irregularly disseminated grains of pyrite up to 0.1 mm across occur as part of the alteration assemblage, mostly in association with the carbonate-chlorite patches. A single grain of detrital chromite has been observed.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 60%, quartz 25%, chlorite 10%, carbonate 3%, sericite and muscovite 1% and traces of rutile, chromite, pyrite and ?carbonaceous material.

Interpretation and Comments: It is interpreted that the sample represents a medium to coarse grained volcanoclastic sandstone with intermediate to felsic volcanic provenance. The rock contains abundant altered lithic detrital grains (fine grained and locally porphyritic and flow-foliated intermediate volcanic material), plus altered plagioclase grains, quartz and a little detrital muscovite. Detrital components occur in a fine grained quartzofeldspathic matrix.

The rock has undergone pervasive propylitic alteration to develop an assemblage of dominant albite, with subordinate quartz and chlorite, minor carbonate, a little sericite and trace rutile and pyrite.

378164 TS

Summary: Medium grained quartz-lithic sandstone with a mixed provenance dominated by grains of siliceous metamorphic material, possible felsic plutonic, fine grained sedimentary, volcanic and trace ultramafic material. The rock has undergone moderate alteration, with development of chlorite and carbonate, mainly from replacement of volcanic grains, matrix and development of cement. A trace of disseminated pyrite occurs as part of the alteration assemblage.

Handspecimen: The sample is composed of a relatively massive, grey medium grained sandstone, probably with a significant amount of detrital lithic grains and quartz, and also with scattered muscovite flakes. There are a few fine grained dark grey lithic grains that might be composed of carbonaceous sedimentary material. Largest detrital grains are up to 1-2 mm across. The rock may have undergone mild chloritic alteration and testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the sample has a moderately well preserved relict detrital grain texture. Detrital grains are sub-rounded to angular and although most are <0.5 mm across, a few grains are up to 2.5 mm across. Individual grains of quartz are the most abundant detrital grain type, but there is a significant population of lithic grains, plus scattered muscovite flakes, rare grains of altered plagioclase, carbonate, FeTi oxide, zircon, tourmaline, biotite and chromite. Lithic grains are dominated by fine to medium grained quartzite, some of which is foliated and some containing a few grains of muscovite. There is a minor proportion of fine grained carbonaceous grains – probably sericitic and shaly in composition, but darkly pigmented by fine carbonaceous material. There are also a few possible altered fine grained volcanic lithic grains. Larger detrital grains occur in a relatively minor matrix component of smaller grains, plus minor cement, mainly carbonate and chlorite. The rock is considered to be a quartz-lithic sandstone, based on relict texture and compositions of the lithic grains. Provenance is mainly siliceous metamorphic material, possible felsic plutonic, fine grained sedimentary, volcanic and trace ultramafic material (e.g. the latter indicated by the presence of a trace of detrital chromite).

b) Alteration and structure: The rock has undergone moderate pervasive alteration, maybe due to very low grade metamorphism. Very weak foliation is present and manifest by slight preferred orientation of elongate lithic grains and muscovite flakes. Alteration is mainly indicated by replacement of fine grained volcanic lithic grains by chlorite \pm carbonate \pm leucoxene \pm pyrite, and FeTi oxide by leucoxene, as well as by development of cement of chlorite and carbonate, with traces of leucoxene, pyrite and hematite. The alteration assemblage is considered to be of propylitic type. Slight weathering effects imposed on the sample are demonstrated by partial replacement of pyrite grains by goethite.

c) Mineragraphy and paragenesis: A few irregularly disseminated grains of pyrite up to 0.1 mm across occur as part of the alteration assemblage. Rare detrital chromite has been observed.

Mineral Mode: Approximate modal proportions are: quartz 70%, chlorite 15%, carbonate 9%, muscovite + sericite 3%, ?carbonaceous material and plagioclase each 1% and traces of biotite, zircon, tourmaline, chromite, pyrite, goethite, hematite and leucoxene.

Interpretation and Comments: It is interpreted that the sample is a medium grained quartz-lithic sandstone with a mixed provenance dominated by grains of siliceous metamorphic material, possible felsic plutonic, fine grained sedimentary, volcanic and trace ultramafic material. The rock has undergone moderate alteration, with development of chlorite and carbonate, mainly from replacement of volcanic grains, matrix and development of cement. A

trace of disseminated pyrite occurs as part of the alteration assemblage which is interpreted to be of propylitic type and may be due to very low grade metamorphism.

378165 TS

Summary: Medium grained quartz-lithic sandstone containing detrital grains of quartz, subordinate amount of lithic material (quartzite and quartz-muscovite schist), scattered grains of muscovite, a little altered biotite, K-feldspar and carbonate and traces of tourmaline, rutile and chromite. The minor amount of matrix component has been recrystallised as a result of low grade metamorphism and consists of quartz, chlorite, carbonate and a little sericite. Rare pyrite grains might have also formed as a result of matrix alteration. The rock is likely to have had a provenance from a mature silicic metamorphic source, rather than from a volcanic source.

Handspecimen: The sample is composed of a relatively massive, medium grained, grey sandstone. It is rather quartz-rich, with largest grains up to 2 mm across. There are also a few scattered muscovite flakes and possible lithic grains. Weak fracturing has occurred and some fractures are coated by weathering-derived goethite. Testing of the section offcut with sodium cobaltinitrite revealed a few small K-feldspar grains. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict detrital grain texture is well preserved and it is clear that the rock is a medium grained sandstone. There is a dominance of tightly packed detrital grains, with only a minor matrix component. The rock contains angular to sub-rounded detrital grains up to 1.5 mm across, with quartz being abundant. There is a subordinate population of lithic grains (mostly fine grained quartzite and quartz-muscovite schist), with scattered detrital muscovite flakes up to 1 mm across, and a few altered biotite flakes, carbonate grains, rare chlorite, K-feldspar and traces of tourmaline, rutile and chromite. The matrix has been altered and is fine grained, consisting largely of quartz and chlorite, with minor carbonate, a little sericite and traces of pyrite and dark ?carbonaceous material. It is interpreted that the sandstone has a provenance from a silicic, metamorphic source (with trace chromite also implying some ultramafic rock input), rather than a volcanic source.

b) Alteration and structure: The rock has undergone low grade alteration, probably as a result of incipient metamorphism. It has also been weakly deformed, with a slight preferred orientation of detrital grains, e.g. the phyllosilicates. Detrital biotite grains have been replaced by chlorite and sericite and the matrix has been replaced by fine grained quartz, chlorite, carbonate and a little sericite. It is possible that a few small pyrite grains grew in the matrix as a result of alteration. The rock has been slightly affected by later supergene oxidation, with pyrite grains having been partly replaced by goethite.

c) Mineragraphy and paragenesis: A few irregularly disseminated grains of pyrite up to 0.1 mm across occur as part of the alteration assemblage, with subsequent partial replacement by supergene goethite. Rare grains of detrital chromite have been observed.

Mineral Mode: Approximate modal proportions are: quartz 80%, chlorite 10%, muscovite + sericite 5%, carbonate 4% and traces of K-feldspar, tourmaline, rutile, chromite, pyrite, goethite and ?carbonaceous material.

Interpretation and Comments: It is interpreted that the sample is a quartz-lithic, medium grained sandstone that has been derived largely from a silicic, metamorphic source, rather than a volcanic source. It contains detrital grains of quartz, subordinate amount of lithic material (quartzite and quartz-muscovite schist), scattered grains of muscovite, a little altered biotite, K-feldspar and carbonate and traces of tourmaline, rutile and chromite. The minor amount of matrix component has been recrystallised as a result of low grade metamorphism and consists of quartz, chlorite, carbonate and a little sericite. Rare pyrite grains might have also formed as a result of matrix alteration.

378166 TS

Summary: Well laminated carbonaceous shale-siltstone. The rock contains detrital grains of quartz and muscovite, with minor lithics and K-feldspar in a fine grained matrix of chlorite, with minor sericite, quartz and carbonaceous material. The latter might represent former organic material, subsequently matured into a graphite-like substance. It is locally accompanied by traces of fine grained pyrite. The rock may have undergone very low grade metamorphism and the mica flakes display a weak preferred orientation.

Handspecimen: The sample is composed of a well laminated, dark grey fine grained sedimentary rock, probably a type of carbonaceous shale. Laminations are generally planar and on a millimetric scale, with slight variations from lighter to darker colour. The paler laminae may be slightly coarser grained and contain more quartz and feldspar, whereas the darker laminae are finer grained and more carbonaceous. Small flakes of muscovite can be seen on the bedding planes. Staining of the section offcut with sodium cobaltinitrite indicated that minor K-feldspar is present, mainly in the paler laminae. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict sedimentary bedding laminations and detrital grain texture are well preserved. Planar bedding laminations are on a scale of ~0.2 mm to 3 mm in thickness, with variations in grain size and in the relative proportion of detrital quartz and muscovite grains, and also in the proportion of dark carbonaceous pigmentation. There is a range from shale laminae (grain size typically <0.05 mm) to siltstone laminae (detrital grain size up to 0.3 mm) with some laminae showing slight grading of grains. Detrital grains are angular to sub-rounded and are dominated by quartz and muscovite, with minor fine grained lithics (sericite-rich), K-feldspar, chlorite and traces of biotite, leucoxene and tourmaline. Quartz is more abundant in the silty laminae and muscovite in the shaly laminae. Interstitial to the detrital grains is a fine grained matrix dominated by chlorite, with minor sericite, quartz, carbonaceous material and a trace of pyrite. The carbonaceous material is probably a graphitic substance and tends to be more abundant in the shaly laminae. The characteristics of the rock indicate that it is a laminated carbonaceous shale-siltstone.

b) Alteration and structure: The rock has undergone low grade alteration, probably as a result of incipient metamorphism. It has also been weakly deformed, with a slight preferred orientation of detrital muscovite grains that is parallel with the bedding laminations. Matrix material may have initially been clayey and has been replaced by chlorite, with minor sericite and quartz. Former organic material has been matured into a graphitic substance and there is a trace of pyrite.

c) Mineragraphy and paragenesis: The rock contains traces of finely disseminated pyrite up to 0.05 mm across as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: muscovite + sericite 35%, quartz 30%, chlorite 25%, K-feldspar 7%, carbonaceous material 2% and traces of biotite, leucoxene, tourmaline and pyrite.

Interpretation and Comments: It is interpreted that the sample is a well laminated carbonaceous shale-siltstone. The rock contains detrital grains of quartz and muscovite, with minor lithics and K-feldspar in a fine grained matrix of chlorite, with minor sericite, quartz and carbonaceous material. The latter might represent former organic material, subsequently matured into a graphite-like substance. It is locally accompanied by traces of fine grained pyrite. The rock may have undergone very low grade metamorphism and the mica flakes display a weak preferred orientation.

378167 TS

Summary: Strongly altered medium to coarse grained lithic-crystal felsic tuff. The rock contains tightly packed lithic grains (mostly altered pumice) and altered plagioclase grains, with minor quartz, in a finer grained pumiceous matrix. There has been replacement of the igneous material by albite, quartz, chlorite, K-feldspar, sericite and traces of leucoxene and pyrite, with the alteration assemblage being of propylitic type. There is no textural evidence for the rock to represent reworked volcanoclastic material (i.e. being an epiclastic sandstone).

Handspecimen: The sample is composed of a massive, grey, medium to coarse grained tuff or epiclastic sandstone. It contains tightly packed lithic grains up to 4 mm across as well as abundant smaller grains of feldspar. The rock may have undergone moderate chlorite alteration. Staining of the section offcut with sodium cobaltinitrite indicated that a moderate amount of K-feldspar is present. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, it is apparent from moderately well preserved relict texture that the rock is most likely a lithic crystal felsic tuff of felsic composition. There is little textural evidence of reworking to form an epiclastic sandstone. There are abundant lithic fragments up to 3 mm across and also abundant altered plagioclase grains up to 2 mm across, along with less common quartz grains up to 0.8 mm across and rare grains of muscovite and altered FeTi oxide. Most lithics represent former pumice fragments, with relict frothy and flow-foliated textures. There are one or two lithic fragments that represent altered fine grained porphyritic volcanic rock (plagioclase phenocrysts in fine grained groundmass) as well as rare lithics composed of fine grained (muscovite) quartzite. In-between the lithic and crystal components there is a minor matrix component, composed of finer grained pumiceous material, including tiny altered glass shard fragments. The relict textures suggest that the fragments are very largely of volcanic origin, but that there is a small proportion of metamorphic (?basement) fragments (e.g. quartzite and rare muscovite grains).

b) Alteration and structure: There has been pervasive strong alteration, maybe due to very low grade metamorphism and/or hydrothermal processes. Plagioclase grains have been replaced by albite and subsequently, abundant sericite. All volcanic lithic fragments have been replaced, mainly by fine grained assemblages of albite, chlorite, K-feldspar, quartz and trace leucoxene and pyrite. Rare porphyritic volcanic fragments show replacement of groundmass material by chlorite. Former igneous FeTi oxide grains have been replaced by leucoxene. The alteration assemblage is considered to be of propylitic type. Later, there has been incipient weathering, leading to local slight goethite staining.

c) Mineralogy and paragenesis: The rock contains a few aggregates of disseminated pyrite up to 0.4 mm across as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 40%, chlorite 23%, quartz 20%, K-feldspar 10%, muscovite + sericite 6% and traces of leucoxene, pyrite and goethite.

Interpretation and Comments: It is interpreted that the sample represents a former medium to coarse grained lithic-crystal felsic tuff. The rock originally contained tightly packed lithic grains (mostly altered pumice) and altered plagioclase grains, with minor quartz, in a finer grained pumiceous matrix. Strong propylitic alteration has led to replacement of the igneous material by albite, quartz, chlorite, K-feldspar, sericite and traces of leucoxene and pyrite. There is no textural evidence for the rock to represent reworked volcanoclastic material (i.e. being an epiclastic sandstone).

378168 TS

Summary: Very fine grained altered felsic vitric ash or derived epiclastic siltstone. The rock is massive and un-laminated and dominated by very finely recrystallised matrix material in which there are scattered small detrital grains of quartz and altered volcanic material, including possible glass shard material. The matrix may also have been dominated by ultrafine vitric ash. There has been complete alteration and recrystallisation of the rock except for small relict quartz grains, with replacement by quartz, K-feldspar, sericite/illite and trace leucoxene. The matrix contains scattered diffuse aggregates containing a slightly higher content of sericite/illite.

Handspecimen: The sample is composed of a relatively massive, but locally fractured, pale buff to pale grey coloured fine grained siltstone or cherty argillite. It is likely that the rock has a significant fine volcanoclastic component. The rock is rather quartz-rich, but also contains sericite and staining of the section offcut with sodium cobaltinitrite indicated that K-feldspar is moderately abundant. Minor goethite staining occurs along fractures and is the result of weathering. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the rock is generally very fine grained, but there are scattered small relict detrital grains up to 0.2 mm across. The latter constitute about 5 volume % of the sample and include quartz and fine grained sericitic altered lithics. There are also a few grains that have relict outlines after former glass shard fragments. No definite relict textures are recognisable in the very fine grained matrix, but it is speculated that it represents former fine grained vitric ash, perhaps reworked and redeposited (although no bedding laminations are apparent). The sample is tentatively interpreted as representing an altered fine felsic volcanic ash or its reworked equivalent, e.g. epiclastic siltstone.

b) Alteration and structure: The original volcanic or epiclastic rock has been pervasively altered and very finely recrystallised. The matrix consists of very finely granular quartz and K-feldspar, plus minor sericite/illite and traces of leucoxene and relict zircon. There are scattered diffuse "spots" up to 0.4 mm across in which sericite/illite is more abundant. Former small vitric clasts have been replaced by sericite and/or quartz and K-feldspar. The sample contains traces of goethite, forming tiny aggregates, maybe as a result of incipient weathering. Better mineralogical characterisation of this sample would be made by using XRD analysis, as the material is very fine grained.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. It is possible that some of the tiny goethite aggregates might have replaced former pyrite grains.

Mineral Mode: Approximate modal proportions are: quartz 60%, K-feldspar 30%, sericite/illite 10% and traces of leucoxene, zircon and goethite.

Interpretation and Comments: It is interpreted that the sample is a very fine grained altered felsic vitric ash or derived epiclastic siltstone. The rock is massive and un-laminated and dominated by very finely recrystallised matrix material in which there are scattered small detrital grains of quartz and altered volcanic material, including possible glass shard material. The matrix may also have been dominated by ultrafine vitric ash. There has been complete alteration and recrystallisation of the rock except for small relict quartz grains, with replacement by quartz, K-feldspar, sericite/illite and trace leucoxene. The matrix contains scattered diffuse aggregates containing a slightly higher content of sericite/illite.

378173 TS

Summary: Coarse grained felsic pyroclastic rock, probably representing a lithic-dominated type, with a small crystal component. There is no textural evidence for the components of the rock to have been substantially reworked so as to form an epiclastic sandstone. The dominant lithic fragments are altered pumiceous material and the small amount of matrix is also pumiceous, with altered glass shard fragments. Individual mineral grains are represented by a few relict volcanic quartz and altered plagioclase and ferromagnesian grains. The rock has undergone strong, pervasive alteration to an assemblage dominated by albite, quartz and sericite, with minor chlorite and carbonate, plus traces of leucoxene and pyrite. The assemblage is of propylitic type and may have formed by very low grade metamorphism (e.g. attending the formation of a weak foliation) and/or due to fluid interaction.

Handspecimen: The sample is composed of a weakly foliated, pale yellowish-grey, strongly altered medium to coarse grained felsic pyroclastic or epiclastic rock. It has a vaguely preserved fragmental texture and contains a few small relict quartz grains. The rock appears to have undergone sericite-quartz alteration, with possible formation of a few small carbonate aggregates. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, moderately preserved relict texture implies that the rock is a type of rather coarse grained pyroclastic of felsic volcanic composition. There are abundant, tightly packed, angular to irregular volcanic lithic fragments up to 5 mm across, with a small population of individual mineral grains and rare altered fine grained sedimentary lithic grains (e.g. siltstone). The volcanic lithic fragments are composed of pumiceous material (preserving flow foliation, elongate bubble textures) and there is a small amount of matrix material that is dominated by small, altered pumiceous fragments including altered glass shards. Individual mineral grains are dominated by volcanic-derived quartz grains up to 1 mm across (former phenocrysts) along with a few altered plagioclase and ferromagnesian grains also up to 1 mm across, and a trace of FeTi oxide. The tightly packed lithics exhibit a weak foliation due to alignment of elongate fragments. There is no diagnostic evidence for the components of the rock to have undergone sedimentary transport and deposition, i.e. there is little to indicate that the rock represents an epiclastic sandstone.

b) Alteration and structure: The interpreted pyroclastic rock has undergone strong and pervasive alteration, with almost complete recrystallisation (except for relict quartz grains). The dominant volcanic lithic and matrix material has been replaced by fine grained albite and quartz, with subordinate amounts of sericite, minor chlorite and carbonate and traces of leucoxene and pyrite. However, some volcanic fragments have been replaced more strongly by sericite or by chlorite, and in places there are a few carbonate porphyroblasts up to 2 mm across. Uncommon plagioclase grains have been replaced by albite, ferromagnesian grains by carbonate \pm chlorite, and FeTi oxide by leucoxene. Weak deformation effects may have been imposed during or after alteration, as alteration-derived sericite locally displays a weak foliation. The alteration assemblage is considered to be of propylitic type and it was later affected by slight weathering, leading to a small amount of goethite forming by alteration of carbonate (presumably Fe-bearing) and pyrite.

c) Mineragraphy and paragenesis: The sample contains traces of pyrite as part of the alteration assemblage. Largest grains are up to 0.1 mm across.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 40%, quartz 35%, sericite 14%, chlorite and carbonate each 5% and traces of leucoxene, pyrite and goethite.

Interpretation and Comments: It is interpreted that the sample represents a coarse grained felsic pyroclastic rock. It is lithic-dominated, with a small crystal component. There is no diagnostic textural evidence for the components of the rock to have been substantially reworked so as to form an epiclastic sandstone. The dominant lithic fragments are altered pumiceous material and the small amount of matrix is also pumiceous, with altered glass shard fragments. Individual mineral grains are represented by a few relict volcanic quartz and altered plagioclase and ferromagnesian grains. The rock has undergone strong, pervasive alteration to an assemblage dominated by albite, quartz and sericite, with minor chlorite and carbonate, plus traces of leucoxene and pyrite. The assemblage is of propylitic type and may have formed by very low grade metamorphism (e.g. attending the formation of a weak foliation) and/or due to fluid interaction.

378174 TS

Summary: Altered porphyritic quartz micromonzodiorite, with moderately well preserved texture showing abundant plagioclase phenocrysts, a few quartz phenocrysts and glomeroporphyritic aggregates (originally with plagioclase \pm ferromagnesian material \pm quartz \pm FeTi oxide) in a fine to medium grained groundmass of plagioclase, altered ferromagnesian material, interstitial K-feldspar and quartz, and disseminated FeTi oxide. There is no textural evidence to indicate that the rock represents a clastic sedimentary type, e.g. epiclastic sandstone. There has been pervasive strong alteration of propylitic type imposed, with replacement of some of the igneous phases by albite, plus subordinate chlorite and minor sericite, carbonate and hematite. Later weathering effects have caused the development of scattered goethite aggregates.

Handspecimen: The sample is composed of a massive, medium grained, apparently porphyritic intermediate igneous rock. It is speckled dark brown-pink to green-grey in colour, with abundant feldspar and altered ferromagnesian material. Staining of the section offcut with sodium cobaltinitrite indicated that there is a moderate amount of K-feldspar present. Alteration of the rock has led to chloritisation of ferromagnesian material, with subsequent weathering having caused the formation of scattered small goethite aggregates. The sample is moderately magnetic, with susceptibility up to 240×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic (igneous) texture is moderately well preserved. There is no textural evidence for the rock to represent a clastic sedimentary type, e.g. an epiclastic sandstone. The rock contains abundant pseudomorphs after former tabular to blocky plagioclase phenocrysts up to 3 mm across, as well as rare quartz phenocrysts up to 1.5 mm across, enclosed in a fine to medium grained, holocrystalline groundmass consisting of abundant plagioclase, altered ferromagnesian material, interstitial K-feldspar and quartz, disseminated FeTi oxide (e.g. titanomagnetite) and a trace of apatite. The sample also contains a few glomeroporphyritic aggregates up to 5 mm across (micro-enclaves) that contained medium to coarse grained plagioclase \pm ferromagnesian material \pm quartz \pm FeTi oxide. The relict texture and interpreted primary mineralogy of the sample imply that it represents an altered porphyritic quartz micromonzodiorite, likely to have been emplaced as a shallow intrusive.

b) Alteration and structure: The rock has sustained strong pervasive alteration of propylitic type, maybe as a result of very low grade metamorphism and/or interaction with fluids such as heated seawater. All plagioclase has been replaced by albite, with further minor flecking by chlorite, sericite and carbonate. Groundmass K-feldspar is slightly altered to chlorite and sericite. All ferromagnesian material has been altered, mostly to chlorite, although some patches are largely replaced by sericite. A little carbonate and traces of leucoxene and hematite also occur at altered ferromagnesian sites. Igneous FeTi oxide has been partly replaced by hematite \pm leucoxene. The sample has been affected by later imposed weathering effects, causing much of the alteration-derived carbonate (presumably Fe-bearing) to have been replaced by goethite.

c) Mineragraphy and paragenesis: No sulphides have been observed. The sample contains traces of relict igneous FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 60%, chlorite 12%, quartz and K-feldspar 10%, sericite 3%, goethite 2%, carbonate and hematite each 1% and traces of FeTi oxide, leucoxene and apatite.

Interpretation and Comments: It is interpreted that the sample represents an altered porphyritic quartz micromonzodiorite, probably emplaced as a shallow intrusive. There is no textural evidence for the rock having had a clastic sedimentary origin and that it represents an epiclastic sandstone. The rock has abundant altered plagioclase phenocrysts, a few quartz

phenocrysts and glomeroporphyritic aggregates (originally with plagioclase \pm ferromagnesian material \pm quartz \pm FeTi oxide) in a fine to medium grained groundmass of plagioclase, altered ferromagnesian material, interstitial K-feldspar and quartz, and disseminated FeTi oxide. There has been pervasive strong alteration of propylitic type imposed, with replacement of some of the igneous phases by albite, plus subordinate chlorite and minor sericite, carbonate and hematite. Later weathering effects have caused the development of scattered goethite aggregates.

378175 TS

Summary: Porphyritic and locally amygdaloidal clinopyroxene latite, with scattered relict clinopyroxene phenocrysts and pseudomorphs after small plagioclase phenocrysts. The fine grained groundmass was rich in plagioclase, K-feldspar and ferromagnesian material and contained a few amygdules. The rock has been strongly and pervasively altered to a propylitic assemblage, probably due to very low grade metamorphism, with replacement of the rock (except for relict clinopyroxene and FeTi oxide) and filling of amygdules by an assemblage of albite, quartz, chlorite, pumpellyite and a little epidote. The rock has been locally brecciated and network veined by quartz, with minor chlorite, epidote and carbonate.

Handspecimen: The sample is composed of a relatively massive, dark green-grey altered porphyritic intermediate volcanic rock. It contains scattered dark green-black ferromagnesian phenocrysts up to 3 mm across in a fine grained feldspathic groundmass in which there is probably minor ferromagnesian material and cut by a few thin network veins, probably containing quartz. Staining of the section offcut with sodium cobaltinitrite indicated that there is a moderate amount of K-feldspar present. The sample contains minor magnetite as it is moderately to strongly magnetic, with susceptibility up to 1160×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, the rock has a moderately preserved relict porphyritic texture and in places, there is some evidence for former amygdules up to 2 mm across. However, the rock is strongly altered and veined. There are scattered variably altered relict subhedral clinopyroxene phenocrysts up to 2 mm across and a few pseudomorphs after former small plagioclase phenocrysts up to 1 mm across. The phenocrystal phases occur in a fine grained and locally amygdular groundmass that is strongly altered, but originally likely to have contained plagioclase, K-feldspar, ferromagnesian material and a little disseminated (relict) FeTi oxide (e.g. titanomagnetite). The relict texture and likely primary minerals indicate that the rock represents a porphyritic and slightly amygdular latite.

b) Alteration and structure: The original volcanic rock has been strongly altered, with local zones of microbrecciation and network veining. Relict clinopyroxene phenocrysts are partly replaced by chlorite, along with a little epidote and pumpellyite. Former plagioclase has been albitised and also replaced by epidote and pumpellyite, and perhaps quartz. The groundmass component is strongly replaced by fine grained pumpellyite, chlorite, albite, K-feldspar and quartz. Amygdules have been mainly filled by quartz (locally sub-radiating) and chlorite, with a little epidote, pumpellyite and carbonate. Zones of microbrecciation and network veining are common, with veins being irregular and up to 2 mm wide. They are mostly filled by fine to medium grained quartz (commonly in sub-radiating aggregates), but there are smaller amounts of chlorite, epidote, a little carbonate and trace hematite. The alteration and vein assemblages are consistent with propylitic type and may have developed as a result of very low grade metamorphism. However, the abundance of veins and quartz infill indicates substantial hydrothermal fluid flow.

c) Mineragraphy and paragenesis: No sulphides have been observed. The sample contains a little relict igneous FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 35%, chlorite 22%, quartz and K-feldspar each 15%, pumpellyite 8%, epidote 3%, carbonate and FeTi oxide each 1% and a trace of hematite.

Interpretation and Comments: It is interpreted that the sample is a porphyritic and locally amygdaloidal clinopyroxene latite. It has scattered relict clinopyroxene phenocrysts and pseudomorphs after small plagioclase phenocrysts. The fine grained groundmass was rich in plagioclase, K-feldspar and ferromagnesian material and contained a few amygdules. The rock has been strongly and pervasively altered to a propylitic assemblage, probably due to very low grade metamorphism, with replacement of the rock (except for relict clinopyroxene

and FeTi oxide) and filling of amygdules by an assemblage of albite, quartz, chlorite, pumpellyite and a little epidote. The rock has been locally brecciated and network veined by quartz, with minor chlorite, epidote and carbonate.

378176 TS

Summary: Very coarse grained intermediate volcanic fragmental rock, e.g. agglomerate, with rather tightly packed porphyritic and amygdaloidal fragments. The original rock may have been of andesite or latite composition and had scattered plagioclase and possible ferromagnesian phenocrysts in a fine grained groundmass. There has been strong and pervasive alteration of propylitic type imposed, probably as a result of very low grade metamorphism. The original igneous minerals have been largely replaced by albite, epidote and chlorite, with minor K-feldspar, pumpellyite and quartz.

Handspecimen: The sample is composed of a very coarse grained intermediate composition volcanic fragmental rock. There are angular to sub-rounded fragments up to 5 cm across that are relatively tightly packed, although in places there is an evident finer grained matrix component. The rock ranges in colour from dull yellow-green to dark brown-green and dark green and fragments possibly retain relict porphyritic and amygdaloidal textures. There has probably been alteration to abundant epidote and chlorite, with a little hematite in places. Staining of the section offcut with sodium cobaltinitrite indicated that there is a moderate amount of K-feldspar present. The sample is weakly magnetic, with susceptibility up to 65×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic and amygdaloidal textures are moderately well preserved and it is evident that the rock is coarsely fragmental, i.e. there are domains with different relict textural characteristics on the several millimetre to several centimetre scale. Most fragments are porphyritic and amygdaloidal, with pseudomorphs after scattered phenocrysts of plagioclase and possible ferromagnesian phases up to 2.5 mm across. Amygdules are rather abundant and are up to 3 mm across. Original fine grained groundmass material is strongly altered, but is suspected of originally being dominated by plagioclase, K-feldspar and ferromagnesian components. Fragments are relatively tightly packed, but minor matrix material appears to be simply composed of smaller fragments. The rock is interpreted to represent a coarse fragmental (e.g. agglomerate) and be of intermediate composition, perhaps latite or (high-K) andesite.

b) Alteration and structure: The fragmental rock has been strongly altered, probably as a result of very low grade metamorphism and maybe involving interaction with heated seawater. There has been replacement of most igneous components, maybe except former K-feldspar. Plagioclase has been albitised, but also locally replaced by epidote, chlorite and pumpellyite. Possible ferromagnesian material has been replaced by fine grained aggregates of one or more of epidote, chlorite, pumpellyite and quartz. All volcanic groundmass material has been replaced by abundant fine grained epidote, with smaller amounts of albite, K-feldspar, chlorite, pumpellyite and traces of leucoxene and hematite. Finer matrix material in-between the fragments tends to be dominated by albite, with smaller amounts of chlorite and K-feldspar, a little quartz, epidote and pumpellyite and traces of hematite and leucoxene. Amygdules are filled by fine grained aggregates of albite \pm chlorite \pm quartz. The alteration assemblage is considered to be of propylitic type.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 50%, epidote 20%, chlorite 13%, K-feldspar 10%, pumpellyite 4%, quartz 2% and traces of hematite and leucoxene.

Interpretation and Comments: It is interpreted that the sample is a very coarse grained intermediate volcanic fragmental rock, e.g. agglomerate, with rather tightly packed porphyritic and amygdaloidal fragments. It could have been of andesite or latite composition, with scattered former plagioclase and possible ferromagnesian phenocrysts in a fine grained groundmass. There has been strong and pervasive alteration of propylitic type imposed,

probably as a result of very low grade metamorphism. The original igneous minerals have been largely replaced by albite, epidote and chlorite, with minor K-feldspar, pumpellyite and quartz.

378177 TS

Summary: Medium grained, inequigranular texture quartz monzonite, probably representing an intrusive. The rock contained an original igneous assemblage of plagioclase, biotite, pyroxene and/or hornblende, interstitial K-feldspar and quartz, and disseminated FeTi oxide (titanomagnetite). Moderate to strong and pervasive alteration of propylitic type has been imposed, with some replacement of igneous minerals by albite, actinolite, chlorite and epidote. There are also a couple of veins containing epidote, albite and minor quartz.

Handspecimen: The sample is composed of a relatively massive, but locally veined, speckled pink and grey-green coloured altered felsic igneous rock. It contains abundant feldspar and subordinate amounts of altered ferromagnesian material and quartz. Staining of the section offcut with sodium cobaltinitrite indicated that K-feldspar is moderately abundant. Ferromagnesian material appears to have been replaced by chlorite and there are a couple of sub-planar epidote veins up to 2 mm wide. The sample contains disseminated magnetite and is strongly magnetic, with susceptibility up to 3650×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict igneous texture is well preserved despite pervasive alteration. The rock is medium (to coarse) grained, with an inequigranular texture. There is a grainsize range of 0.1-3 mm, with somewhat larger grains of plagioclase, K-feldspar and ferromagnesian phases. The rock contains abundant blocky altered grains of plagioclase, altered ferromagnesian material in elongate, prismatic and blocky grains, interstitial to blocky grains of K-feldspar, subordinate amounts of interstitial quartz, disseminated FeTi oxide (titanomagnetite) and traces of apatite. Relict shapes of the altered ferromagnesian grains suggest that biotite was rather abundant (in fact there is a trace of relict biotite) and that the prismatic to blocky grains were composed of pyroxene and/or hornblende. The rock contains a couple of small medium grained glomeroporphyritic aggregates (micro-enclaves) rich in altered ferromagnesian material and FeTi oxide. The relict texture and interpreted primary mineralogy of the sample indicates that it is a quartz monzonite, likely to have been emplaced as an intrusive.

b) Alteration and structure: The igneous rock has sustained moderate to strong pervasive alteration of propylitic type. All plagioclase has been albitised and also locally flecked by epidote and chlorite. Former pyroxene and/or hornblende has been replaced by actinolite and a little chlorite, and most biotite has been replaced by chlorite, with local epidote and trace leucoxene. K-feldspar is lightly dusted by hematite pigmentation. A couple of sub-planar veins up to 1 mm wide cut the altered rock and contain medium grained epidote, albite and minor quartz. Slight weathering effects have been imposed on the sample, with local staining by goethite.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There are scattered relict igneous grains of FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 35%, K-feldspar 30%, quartz 14%, actinolite and chlorite each 7%, epidote 4%, FeTi oxide 2% and traces of leucoxene, biotite, apatite, hematite and goethite.

Interpretation and Comments: It is interpreted that the sample is a medium grained, inequigranular texture quartz monzonite, probably representing an intrusive. The rock contained an original igneous assemblage of plagioclase, biotite, pyroxene and/or hornblende, interstitial K-feldspar and quartz, and disseminated FeTi oxide (titanomagnetite). Moderate to strong and pervasive alteration of propylitic type has been imposed, with some replacement of igneous minerals by albite, actinolite, chlorite and epidote. The altered rock has been cut a couple of veins containing epidote, albite and minor quartz. Slight weathering effects have led to local patches of goethite staining.

378178 TS

Summary: Porphyritic clinopyroxene latite, with moderate to strong propylitic alteration and a few amygdules. The rock contains some fresh relict phenocrysts of clinopyroxene, although some are altered to chlorite. Former plagioclase phenocrysts are totally altered. The groundmass of the rock is fine grained and holocrystalline and dominated by K-feldspar and small plagioclase laths. The alteration assemblage is probably due to very low grade metamorphism and comprises albite, chlorite and a little carbonate and sericite; amygdules are largely filled by quartz, with a little carbonate and chlorite. The rock has been cut by one or two thin veins containing quartz, carbonate and chlorite.

Handspecimen: The sample is composed of a massive, dark grey-green altered porphyritic fine grained, intermediate igneous rock. It contains scattered dark green-black ferromagnesian phenocrysts up to 4 mm across and a few altered feldspar phenocryst in a fine grained groundmass. There may have been some chloritisation of the ferromagnesian phenocrysts and of the groundmass. Staining of the section offcut with sodium cobaltinitrite indicated that K-feldspar is moderately abundant in the groundmass. The sample is weakly magnetic, with susceptibility up to 100×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic and amygdular texture is well preserved. The rock contains scattered relict subhedral phenocrysts of clinopyroxene up to 4 mm across (with rare tiny FeTi oxide inclusions) and pseudomorphs after ferromagnesian phenocrysts (most likely to be completely altered clinopyroxene), as well as pseudomorphs after scattered tabular plagioclase phenocrysts up to 2.5 mm across. The phenocrystal phases occur in a fine grained, holocrystalline groundmass consisting of small plagioclase laths up to 0.2 mm long, abundant interstitial K-feldspar, a few small prisms of clinopyroxene and traces of FeTi oxide. In the groundmass, there are a few irregular to ovoid amygdules up to 2 mm across. The texture and mineralogy of the sample are consistent with it representing a porphyritic clinopyroxene latite. It may have been emplaced as a lava or shallow intrusive.

b) Alteration and structure: There has been moderate to strong, pervasive alteration of propylitic type. Original plagioclase has been altered to albite, with further extensive replacement by fine grained sericite, carbonate and chlorite. Although much clinopyroxene is fresh and unaltered, there is a gradation through part-alteration to complete pseudomorphism by chlorite, along with traces of titanite and pyrite, and locally by a minor amount of carbonate. In the groundmass, there has been minor development of chlorite and traces of titanite. Amygdules have been mostly filled by quartz (fine to medium grained, locally radiating and maybe after former chalcedony), with a little carbonate and chlorite. The rock has been cut by one or two extensional veins up to 0.2 mm wide that contain one or more of the phases quartz, carbonate and chlorite.

c) Mineragraphy and paragenesis: There is a tiny trace of pyrite that has formed by alteration of clinopyroxene and is associated with chlorite. There is also a trace of fine grained relict igneous FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: K-feldspar 40%, plagioclase (albite) 25%, clinopyroxene 15%, chlorite 8%, quartz 5%, carbonate and sericite each 3% and traces of titanite, FeTi oxide and pyrite.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic and slightly amygdaloidal clinopyroxene latite. The rock contains relict phenocrysts of clinopyroxene, although some are altered to chlorite. Former plagioclase phenocrysts are totally altered. The groundmass of the rock is fine grained and holocrystalline and dominated by K-feldspar and small plagioclase laths. The alteration assemblage is of propylitic type and is probably due to very low grade metamorphism. It comprises albite, chlorite and a little

carbonate and sericite; amygdules are largely filled by quartz, with a little carbonate and chlorite. The rock has been cut by one or two thin veins containing quartz, carbonate and chlorite.

378179 TS

Summary: Porphyritic rhyodacite, perhaps representing a lava or shallow intrusive. The rock contains relict phenocrysts of quartz as well as altered phenocrysts of plagioclase in a fine grained groundmass dominated by K-feldspar, with minor quartz, plagioclase and altered ferromagnesian material. The rock has undergone moderate to strong propylitic alteration, with development of albite, plus minor chlorite, carbonate and sericite. A few thin extensional veins of quartz (-carbonate-chlorite) cut the altered rock.

Handspecimen: The sample is composed of a massive, fine grained, grey, porphyritic felsic igneous rock. It contains scattered quartz and a few feldspar phenocrysts up to 3-4 mm across in a fine grained quartzofeldspathic groundmass. Only weak alteration appears to have occurred, with minor development of chlorite. Staining of the section offcut with sodium cobaltinitrite indicated that K-feldspar is abundant in the groundmass. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. There are scattered relict embayed quartz phenocrysts up to 2.5 mm across as well as scattered altered tabular plagioclase phenocrysts up to 3.5 mm across, set in a altered and finely recrystallised groundmass. The latter was probably holocrystalline and rich in K-feldspar, along with minor quartz and plagioclase (also occurring as microphenocrysts), altered ferromagnesian material and traces of FeTi oxide (now completely altered) and zircon. The relict texture and interpreted primary mineralogy indicate that the rock is a porphyritic rhyodacite, maybe representing a lava or shallow intrusive.

b) Alteration and structure: The rock has undergone moderate to strong and pervasive alteration and local veining. All plagioclase has been replaced by albite, along with small amounts of fine grained sericite and chlorite. The finely recrystallised groundmass, although dominated by K-feldspar, contains minor albitised plagioclase, quartz, chlorite, carbonate and traces of sericite, hematite, leucoxene and pyrite. The alteration assemblage is consistent with propylitic type. The altered rock has been cut by a few sub-planar extensional veins up to 0.2 mm wide. Although quartz-dominated, the veins also contain minor chlorite and carbonate. Slight weathering effects imposed on the rock have caused local goethite staining.

c) Mineragraphy and paragenesis: There is a tiny trace of pyrite that has formed by alteration, with largest grains up to 0.1 mm across.

Mineral Mode: Approximate modal proportions are: K-feldspar 40%, plagioclase (albite) and quartz each 25%, chlorite 5%, carbonate and sericite each 2% and traces of leucoxene, hematite, zircon, goethite and pyrite.

Interpretation and Comments: It is interpreted that the sample represents a porphyritic rhyodacite, maybe emplaced as a lava or shallow intrusive. The rock contains relict phenocrysts of quartz as well as altered phenocrysts of plagioclase in a fine grained groundmass dominated by K-feldspar, with minor quartz, plagioclase and altered ferromagnesian material. The rock has undergone moderate to strong propylitic alteration, with development of albite, plus minor chlorite, carbonate and sericite. A few thin extensional veins of quartz (-carbonate-chlorite) cut the altered rock.

378180 TS

Summary: Medium grained, inequigranular texture quartz monzonite, probably representing an intrusive. The rock contained an original igneous assemblage of K-feldspar, plagioclase, biotite, pyroxene and/or hornblende, interstitial quartz, disseminated FeTi oxide (titanomagnetite) and traces of titanite and apatite. Moderate to strong and pervasive alteration of propylitic type has been imposed, most likely as a result of very low grade metamorphism. The alteration assemblage is composed of albite, actinolite, chlorite and pumpellyite.

Handspecimen: The sample is composed of a massive, medium grained (up to 2-3 mm), speckled pink and grey-green coloured intermediate to felsic igneous rock, apparently of monzonitic character and probably representing an intrusive. It contains abundant feldspar and a subordinate amount of altered ferromagnesian material and quartz. The ferromagnesian may have been altered to chlorite and amphibole. Staining of the section offcut with sodium cobaltinitrite indicated that K-feldspar is abundant. The sample contains disseminated magnetite and is strongly magnetic, with susceptibility up to 1950×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict igneous texture is well preserved. The rock has a medium grained, inequigranular to slightly porphyritic texture, with largest grains being K-feldspar and plagioclase; these are up to 2 mm across. The feldspar grains are blocky to tabular, although some K-feldspar is anhedral as it forms interstitial masses. The feldspars are intergrown with altered ferromagnesian grains up to 1.5 mm long, subordinate interstitial quartz, minor disseminated FeTi oxide (titanomagnetite) and traces of titanite and apatite. Although ferromagnesian grains are altered, relict shapes indicate that some are likely to have been biotite, whereas others were pyroxene and/or hornblende. The relict texture and inferred primary mineralogy indicate that it represents a quartz monzonite, likely to have been emplaced as an intrusive. The rock has similarities to sample 378177.

b) Alteration and structure: The igneous rock has undergone moderate to strong pervasive alteration. It is probable that all plagioclase has been replaced by albite and small aggregates of pumpellyite. All former biotite has been replaced by chlorite, with traces of epidote, pumpellyite and leucoxene. All former pyroxene and/or hornblende has been replaced by actinolite. Interstitially, fine grained aggregates of pumpellyite up to 1 mm across have been formed. The alteration assemblage is considered to be of propylitic type and to have been the result of very low grade metamorphism.

c) Mineralogy and paragenesis: No sulphides have been observed in the sample. There are scattered relict igneous grains of FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: K-feldspar 40%, plagioclase (albite) 30%, quartz 10%, actinolite 8% chlorite 6%, pumpellyite 3%, FeTi oxide 2% and traces of epidote, titanite, apatite and leucoxene.

Interpretation and Comments: It is interpreted that the sample is a medium grained, inequigranular texture quartz monzonite, probably representing an intrusive. The rock contained an original igneous assemblage of K-feldspar, plagioclase, biotite, pyroxene and/or hornblende, interstitial quartz, disseminated FeTi oxide (titanomagnetite) and traces of titanite and apatite. Moderate to strong and pervasive alteration of propylitic type has been imposed, most likely as a result of very low grade metamorphism. The alteration assemblage is composed of albite, actinolite, chlorite and pumpellyite.

378181 TS

Summary: Porphyritic quartz-clinopyroxene latite, with moderate to strong propylitic alteration. The rock originally contained phenocrysts of plagioclase, clinopyroxene and quartz, with microphenocrysts of FeTi oxide in a fine grained (almost aphanitic) groundmass rich in K-feldspar. The groundmass also hosts a few glomeroporphyritic aggregates of plagioclase-clinopyroxene-FeTi oxide as well as rare small angular xenoliths of siltstone. Pervasive alteration has seen replacement of plagioclase by albite, sericite, epidote and chlorite, variably replacement of clinopyroxene by chlorite \pm epidote and FeTi oxide by hematite and leucoxene. In the groundmass there has been development of replacement patches of epidote \pm chlorite, as well as a trace of pyrite.

Handspecimen: The sample is composed of a massive, grey-green altered porphyritic fine grained intermediate igneous rock. It contains scattered altered feldspar and ferromagnesian phenocrysts up to 4 mm across in a fine grained feldspathic groundmass. The rock has pervasive chlorite-epidote alteration, with ferromagnesian having been altered to chlorite and the development of a few epidote-rich aggregates up to a few millimetres across. Staining of the section offcut with sodium cobaltinitrite indicated that there is abundant K-feldspar in the groundmass. The sample is weakly magnetic, with susceptibility up to 45×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. The rock contains scattered relict subhedral phenocrysts of clinopyroxene up to 2 mm across and a few relict quartz phenocrysts up to 3 mm across. There are scattered pseudomorphs after former tabular plagioclase phenocrysts up to 2 mm across as well as microphenocrysts of FeTi oxide and rare apatite. Several glomeroporphyritic aggregates (micro-enclaves) up to a few millimetres across are present and would have originally been composed of medium grained plagioclase-clinopyroxene-FeTi oxide-trace apatite. The phenocrystal phases occur in a fine grained (almost aphanitic) groundmass dominated by K-feldspar, but with a little plagioclase and quartz. In the groundmass, there are rare angular xenoliths of fine grained siltstone up to 1.5 mm across. From the relict texture and inferred primary mineralogy, the rock is interpreted to be a porphyritic quartz-clinopyroxene latite, maybe representing a lava or shallow intrusive. There is no textural evidence for brecciation.

b) Alteration and structure: There has been moderate to strong alteration imposed, maybe as a result of very low grade metamorphism. All plagioclase has been albitised and also further replaced by fine grained sericite, with a little epidote and chlorite. Clinopyroxene has been variably replaced by chlorite \pm epidote and FeTi oxide has been largely replaced by hematite \pm leucoxene. Minor chlorite and trace pyrite have formed in the groundmass and there has also been patchy groundmass replacement by irregular fine to medium grained aggregates up to several millimetres across of inequigranular epidote and minor chlorite. The alteration assemblage is of propylitic type.

c) Mineragraphy and paragenesis: The rock contains a trace of disseminated pyrite as part of the alteration assemblage. Largest grains are up to 0.2 mm across.

Mineral Mode: Approximate modal proportions are: K-feldspar 50%, plagioclase (albite), chlorite and sericite each 10%, epidote, quartz and clinopyroxene each 6%, hematite 1% and traces of apatite, FeTi oxide, leucoxene and pyrite.

Interpretation and Comments: It is interpreted that the sample is an altered porphyritic quartz-clinopyroxene latite. There is no textural evidence for brecciation. The rock originally contained phenocrysts of plagioclase, clinopyroxene and quartz, with microphenocrysts of FeTi oxide in a fine grained (almost aphanitic) groundmass rich in K-feldspar. The groundmass also hosts a few glomeroporphyritic aggregates of plagioclase-clinopyroxene-FeTi oxide as well as rare small angular xenoliths of siltstone. Moderate to strong, pervasive alteration of propylitic type has caused replacement of plagioclase by albite, sericite, epidote

and chlorite, variably replacement of clinopyroxene by chlorite \pm epidote and FeTi oxide by hematite and leucoxene. In the groundmass there has been development of replacement patches of epidote \pm chlorite, as well as a trace of pyrite.

378182 TS

Summary: Altered and slightly weathered porphyritic quartz monzodiorite. There is no textural evidence for this rock to represent clastic sedimentary material (e.g. sandstone). The original igneous rock contained a few large plagioclase phenocrysts, intergrown with smaller plagioclase grains, ferromagnesian material (mostly pyroxene), late magmatic interstitial quartz and minor K-feldspar, disseminated FeTi oxide and a trace of apatite. The rock may represent a type of shallow intrusive. It has undergone strong alteration of propylitic type, with extensive replacement of igneous minerals by albite, sericite, chlorite and minor leucoxene. Weathering effects have caused degradation of chlorite to nontronite and formation of goethite staining and small aggregates, some of which could be pseudomorphous after former alteration-derived pyrite.

Handspecimen: The sample is composed of a slightly weathered, massive, speckled pink-grey-white, porphyritic medium grained intermediate to felsic igneous rock. A single fine grained enclave about 1 cm across was observed. There are a few altered feldspar phenocrysts up to 5 mm across in a medium grained groundmass composed of dominant feldspar, but with minor altered ferromagnesian material and quartz. It is possible that the rock has undergone sericite-chlorite alteration as well as being slightly weathered, as indicated by the presence of a few small goethite aggregates. Testing of the section offcut with sodium cobaltinitrite indicated that there is only a trace of K-feldspar. The sample is weakly magnetic, with susceptibility up to 55×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic (igneous) texture is moderately well preserved. There is no textural evidence that the rock is of clastic sedimentary origin, i.e. that it represents a sandstone. The rock contains a few large tabular phenocrysts of plagioclase up to 5 mm across, now completely altered. These would have been intergrown with smaller grains of plagioclase, ferromagnesian grains up to 2 mm across, disseminated fine to medium grained FeTi oxide, interstitial late magmatic grains of quartz (up to 0.5 mm across) associated with minor K-feldspar and traces of apatite. Quartz and K-feldspar form rare micrographic intergrowths interstitial to plagioclase. Although all ferromagnesian material is altered, relict shapes suggest that most was originally pyroxene, although a little biotite may have been present. The relict texture and inferred primary mineralogy indicate that the rock represents a porphyritic, medium grained quartz monzodiorite. It may have been emplaced as a shallow intrusive and does not represent a clastic sedimentary rock.

b) Alteration and structure: There has been strong pervasive alteration imposed, as well as minor weathering effects. All plagioclase has been albitised, with further partial to complete replacement by fine grained sericite. All ferromagnesian material has been replaced by chlorite and most FeTi oxide replaced by leucoxene. K-feldspar is pigmented by fine dusty hematite and has also been partly replaced by sericite. The alteration assemblage is of propylitic type and may be due to very low grade metamorphism and/or interaction with fluid such as heated seawater. Weathering effects are manifest by substantial degradation of alteration-derived chlorite to khaki-coloured nontronite, by patchy goethite staining and formation of a few small goethite aggregates, perhaps replacive after original pyrite grains developed during alteration.

c) Mineragraphy and paragenesis: There are no sulphides present, but small goethite aggregates could represent pseudomorphs after former alteration-derived pyrite.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 40%, sericite 30%, chlorite/nontronite 15%, quartz 9% goethite and K-feldspar each 2%, leucoxene 1% and traces of apatite, FeTi oxide and hematite.

Interpretation and Comments: It is interpreted that the sample represents a porphyritic quartz monzodiorite, perhaps emplaced as a shallow intrusive. There is no textural evidence for this rock to represent clastic sedimentary material (e.g. sandstone). The original igneous rock contained a few large plagioclase phenocrysts, intergrown with smaller plagioclase grains, ferromagnesian material (mostly pyroxene), late magmatic interstitial quartz and minor K-feldspar, disseminated FeTi oxide and a trace of apatite. It has undergone strong alteration of propylitic type, with extensive replacement of igneous minerals by albite, sericite, chlorite and minor leucoxene. Subsequent weathering effects have caused degradation of chlorite to nontronite and formation of goethite staining and small aggregates, some of which could be pseudomorphous after former alteration-derived pyrite.

378183 TS

Summary: Altered and slightly weathered medium grained porphyritic microgranodiorite. The original igneous rock contained a few phenocrysts of plagioclase and ferromagnesian material intergrown with medium grained plagioclase, ferromagnesian material, FeTi oxide, and interstitial quartz and K-feldspar. Relict shapes suggest that the ferromagnesian included biotite and pyroxene. There has been strong pervasive alteration imposed, resulting in replacement of plagioclase by albite, epidote, chlorite and sericite, biotite by chlorite and pyroxene by actinolite. The alteration is consistent with propylitic type and was subsequently weakly overprinted by the effects of weathering, leading to goethite staining and minor degradation of chlorite to nontronite.

Handspecimen: The sample is composed of a massive, weakly porphyritic, medium grained intermediate to felsic igneous rock. It is green-grey in colour and has a few phenocrysts of altered plagioclase and ferromagnesian material up to 4 mm across. Ferromagnesian grains appear to have been replaced by chlorite and amphibole. Staining of the section offcut with sodium cobaltinitrite indicated that there is a moderate amount of interstitial K-feldspar. The sample contains minor magnetite as it is rather strongly magnetic, with susceptibility up to 1630×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is moderately well preserved. The rock is medium grained, with a few altered tabular phenocrysts of plagioclase up to 2 mm across and prismatic ferromagnesian material up to 1.5 mm long. These are intergrown with smaller grains, typically in the grainsize range 0.1-1 mm, of plagioclase, altered ferromagnesian material, disseminated FeTi oxide (e.g. titanomagnetite), interstitial quartz and K-feldspar and a trace of zircon. Relict shapes suggest that some of the ferromagnesian material was formerly biotite, whereas prismatic to blocky pseudomorphs probably represent former pyroxene. The relict texture and interpreted primary mineralogy indicate that the rock represents an altered, medium grained porphyritic microgranodiorite. It was probably emplaced as a shallow intrusive.

b) Alteration and structure: The rock has undergone strong pervasive alteration, maybe due to very low grade metamorphism and/or interaction with a fluid such as heated seawater. All plagioclase has been replaced by albite, with minor epidote-clinozoisite, chlorite and sericite. All former biotite has been replaced by chlorite and traces of leucoxene and former pyroxene has been replaced by actinolite with local chlorite and epidote. Igneous FeTi oxide has been slightly altered to hematite and leucoxene. The alteration assemblage is of propylitic type. Subsequently, the rock has been subjected to slight weathering, resulting in some degradation of alteration-derived chlorite to nontronite and the development of minor goethite staining and small aggregates.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There is minor relict disseminated FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 45%, K-feldspar and quartz each 15%, chlorite/nontronite 14%, actinolite 4%, epidote-clinozoisite 3%, FeTi oxide 2%, sericite 1% and traces of goethite, leucoxene, hematite and zircon.

Interpretation and Comments: It is interpreted that the sample represents a medium grained porphyritic microgranodiorite, perhaps emplaced as a shallow intrusive. The original igneous rock contained a few phenocrysts of plagioclase and ferromagnesian material intergrown with medium grained plagioclase, ferromagnesian material, FeTi oxide, and interstitial quartz and K-feldspar. Relict shapes suggest that the ferromagnesian included biotite and pyroxene. There has been strong pervasive propylitic alteration imposed, resulting in replacement of plagioclase by albite, epidote, chlorite and sericite, biotite by chlorite and

pyroxene by actinolite. Later, the rock was weakly overprinted by the effects of weathering, leading to goethite staining and minor degradation of chlorite to nontronite.

378184 TS

Summary: Medium to coarse grained lithic-feldspar-clinopyroxene sandstone, representing a proximal epiclastic, with an immature, intermediate volcanic source, probably of porphyritic clinopyroxene latite composition. Lithic grains are dominated by fine grained volcanics, some of which are porphyritic and others pumiceous. Individual detrital mineral grains are dominated by plagioclase, although there are scattered relict clinopyroxene grains and a minor population of FeTi oxide grains. A small matrix component includes finer volcanic detritus, including altered glass shards. The rock has undergone moderate to strong propylitic alteration, perhaps as a result of very low grade metamorphism, with partial replacement of the former igneous components by albite, chlorite and a little sericite and hematite. Slight weathering effects have led to some degradation of chlorite to nontronite and formation of goethite staining.

Handspecimen: The sample is composed of a massive, medium to coarse grained, clastic-textured rock, with abundant, tightly packed lithic grains up to 8 mm across and feldspar grains up to 5 mm across. The lithic grains appear to be fine grained and probably volcanic in origin and some are porphyritic. They have been strongly altered to chlorite that imparts a dark grey-green colour to the sample. There is also a small amount of red-brown spotting due to hematite. Staining of the section offcut with sodium cobaltinitrite indicated that there is a moderate amount of K-feldspar present. The sample contains minor magnetite as it is moderately magnetic, with susceptibility up to 520×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict medium to coarse grained clastic texture is moderately well preserved. The rock is composed of abundant, tightly packed, angular detrital grains; these are dominated by volcanic lithics up to 7 mm across and altered plagioclase grains up to 4 mm across. There are also relatively abundant relict grains of clinopyroxene (up to 1.5 mm across) and FeTi oxide (e.g. titanomagnetite), along with traces of brown hornblende, zircon and apatite. All of the individual mineral grains are interpreted to have a proximal igneous source. A fine to medium grained matrix component occupies about 15-20 % of the sample and is composed of smaller volcanic lithic grains, altered feldspar and altered glass shards. In the abundant lithic grains, there are preserved textures that show that many grains were composed of porphyritic material (plagioclase and clinopyroxene phenocrysts in a fine grained or aphanitic groundmass), or were fine grained and locally sub-trachytic in texture, or were pumiceous. The volcanic lithic grains and the individual mineral grains indicate that the source material is of intermediate composition and most likely of porphyritic clinopyroxene latite. Such a rock would have been initially rich in plagioclase-clinopyroxene-K-feldspar, with minor FeTi oxide. There would be similarities in the source material to samples 378175 and 378178. It is interpreted that the volcanic source material was proximal and underwent minimal transport, to form a very immature lithic-feldspar-dominated epiclastic sandstone.

b) Alteration and structure: There has been moderate to strong alteration of propylitic type imposed, probably as a result of very low grade metamorphism. All plagioclase has been replaced by albite, with slight flecking by sericite and chlorite. Relict clinopyroxene has been partly altered to chlorite and relict FeTi oxide to hematite and trace leucoxene. The groundmass material in volcanic lithic grains and the matrix component have been commonly strongly chloritised, but elsewhere, there has been replacement by fine grained albite, K-feldspar and chlorite, with traces of hematite, leucoxene and quartz. The rock has been slightly weathered, leading to some degradation of alteration-derived chlorite to khaki-coloured nontronite and the formation of local goethite staining and aggregates.

c) Mineralogy and paragenesis: No sulphides have been observed in the sample. There is a little relict disseminated FeTi oxide (titanomagnetite).

Mineral Mode: Approximate modal proportions are: plagioclase (albite) 60%, K-feldspar and chlorite/nontronite each 15%, clinopyroxene 6%, sericite, FeTi oxide and hematite each 1% and traces of quartz, zircon, apatite, hornblende, goethite and leucoxene.

Interpretation and Comments: It is interpreted that the sample is a medium to coarse grained lithic-feldspar-clinopyroxene sandstone. It is an epiclastic, with a proxima, immature, intermediate volcanic source, probably of porphyritic clinopyroxene latite composition. Lithic grains are dominated by fine grained volcanics, some of which are porphyritic and others pumiceous. Individual detrital mineral grains are dominated by plagioclase, although there are scattered relict clinopyroxene grains and a minor population of FeTi oxide grains. A small matrix component includes finer volcanic detritus, including altered glass shards. The rock has undergone moderate to strong propylitic alteration, perhaps as a result of very low grade metamorphism, with partial replacement of the former igneous components by albite, chlorite and a little sericite and hematite. Slight weathering effects have led to some degradation of chlorite to nontronite and formation of goethite staining.

378185 TS

Summary: Porphyritic and amygdaloidal rhyodacite or quartz latite, with moderate to strong alteration. The rock originally contained a few phenocrysts of plagioclase and microphenocrysts of a ferromagnesian phase, set in a fine grained, holocrystalline groundmass that was dominated by K-feldspar, with subordinate quartz and plagioclase and minor ferromagnesian material. The rock has been affected by propylitic alteration, probably as a result of very low grade metamorphism. There has been replacement by an assemblage of albite and chlorite, with a little sericite and traces of pumpellyite and leucoxene-rutile. Amygdules are partly to complete filled by quartz and chlorite, with a little sericite in places.

Handspecimen: The sample is composed of a massive, porphyritic and amygdular fine grained felsic igneous rock. It is pale grey-brown in colour, with a few feldspar phenocrysts up to 3 mm long and scattered amygdules up to 4 mm across that contain quartz and dark green chlorite. Most of the rock is composed of the fine grained quartzofeldspathic groundmass and staining of the section offcut with sodium cobaltinitrite showed that the groundmass contains abundant K-feldspar. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict medium porphyritic and amygdular textures are well preserved. The sample retains scattered partly altered tabular plagioclase phenocrysts up to 2.5 mm long and there are a few pseudomorphs after former ferromagnesian microphenocrysts (?pyroxene) up to 0.7 mm across and after FeTi oxide grains up to 0.3 mm across. The phenocrystal phases occur in a fine grained, holocrystalline groundmass that is dominated by K-feldspar, with subordinate amounts of intergrown quartz and small plagioclase laths, plus a little altered ferromagnesian material and trace FeTi oxide. In the groundmass, there are scattered ovoid to spheroidal partly to completely filled amygdules up to 4 mm across. The relict texture and interpreted primary mineralogy of the rock indicate that it represents a porphyritic and amygdular rhyodacite or quartz latite.

b) Alteration and structure: The rock has sustained moderate to strong and pervasive alteration, maybe as a result of very low grade metamorphism. Plagioclase has been partly replaced by albite and a little sericite and chlorite, plus trace pyrite, although some relict plagioclase remains. Former ferromagnesian grains have been replaced by fine grained aggregates of chlorite \pm sericite \pm leucoxene/rutile \pm trace pumpellyite, whereas igneous FeTi oxide grains have been replaced by leucoxene/rutile. The groundmass is only weakly altered, with local replacement by chlorite and traces of sericite and leucoxene. Amygdules are largely filled by medium grained quartz, in places accompanied by fine to medium grained chlorite (locally in radiating aggregates) and traces of sericite. The alteration assemblage is consistent with propylitic type.

c) Mineragraphy and paragenesis: A tiny trace of pyrite has been observed in the sample as part of the alteration assemblage.

Mineral Mode: Approximate modal proportions are: K-feldspar 40%, plagioclase (including albite) 35%, quartz 15%, chlorite 7%, sericite 2% and traces of leucoxene/rutile, pumpellyite and pyrite.

Interpretation and Comments: It is interpreted that the sample is a porphyritic and amygdaloidal rhyodacite or quartz latite, perhaps emplaced as a lava or shallow intrusive. The rock originally contained a few phenocrysts of plagioclase and microphenocrysts of a ferromagnesian phase, set in a fine grained, holocrystalline groundmass that was dominated by K-feldspar, with subordinate quartz and plagioclase and minor ferromagnesian material. The rock has been affected by moderate to strong propylitic alteration, probably as a result of very low grade metamorphism. There has been replacement by an assemblage of albite and

chlorite, with a little sericite and traces of pumpellyite and leucoxene-rutile. Amygdules are partly to complete filled by quartz and chlorite, with a little sericite in places.

378186 TS

Summary: Altered porphyritic and locally brecciated rhyodacite, originally containing scattered phenocrysts of plagioclase and less common ferromagnesian material in a glassy groundmass. The latter has devitrified, with relict perlitic cracking being present and there are also zones of brecciation. The rock has undergone pervasive, strong alteration, with replacement of groundmass material by K-feldspar, albite and minor quartz, chlorite, sericite and porphyroblastic carbonate. Plagioclase phenocrysts have been albitised and ferromagnesian grains largely replaced by quartz and carbonate.

Handspecimen: The sample is composed of a relatively massive, mostly grey coloured (but with a few pale brown patches), altered porphyritic felsic volcanic rock. It is fine grained, with scattered altered feldspar phenocrysts in a fine grained groundmass; in places the rock appears to be brecciated. Possible weak chlorite and sericite alteration has occurred. Staining of the section offcut with sodium cobaltinitrite indicated that K-feldspar is abundant. The sample is essentially non-magnetic, with susceptibility of $<20 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, relict porphyritic texture is well preserved. There are scattered pseudomorphs after former tabular to blocky phenocrysts of plagioclase up to 2.5 mm across and less common pseudomorphs after a prismatic ferromagnesian phase (maybe pyroxene originally) up to 5 mm long. A few altered microphenocrysts of FeTi oxide are present as well as uncommon glomeroporphyritic aggregates of plagioclase-altered ferromagnesian material-FeTi oxide-trace apatite up to a few millimetres across. The phenocrystal phases occur in a devitrified glassy groundmass displaying relict perlitic cracking. The groundmass was probably of quartzofeldspathic composition. In places, the originally glassy, porphyritic rock has been brecciated, with small angular fragments occurring in an altered, fine grained matrix. From the relict textures, it is interpreted that the rock could represent a porphyritic rhyodacite, maybe emplaced as a lava, but with some brecciation having occurred, e.g. autobrecciation during flow.

b) Alteration and structure: The volcanic rock has been strongly altered to a propylitic assemblage, maybe due to very low grade metamorphism and/or hydrothermal processes. All plagioclase has been replaced by albite and a small amount of sericite. All former ferromagnesian grains have been replaced by fine grained quartz \pm carbonate \pm a little chlorite and leucoxene. All igneous FeTi oxide has been replaced by leucoxene. The glassy groundmass and breccia matrix have been finely recrystallised into an assemblage of K-feldspar, albite, minor chlorite, quartz, sericite and a few irregular porphyroblasts of carbonate up to several millimetres across. Rare veins and elongate patches up to 0.3 mm wide occur in the altered rock and contain one or more of quartz, chlorite or carbonate.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample.

Mineral Mode: Approximate modal proportions are: plagioclase (albite) and K-feldspar each 30%, quartz 20%, chlorite 10%, carbonate 6%, sericite 4% and traces of apatite and leucoxene.

Interpretation and Comments: It is interpreted that the sample represents an altered porphyritic and locally brecciated rhyodacite, maybe emplaced as a lava, but with some autobrecciation. The rock originally contained scattered phenocrysts of plagioclase and less common ferromagnesian material in a glassy groundmass. The latter has devitrified, with relict perlitic cracking being present and there are also zones of brecciation. The rock has undergone pervasive, strong alteration, with replacement of groundmass material by K-feldspar, albite and minor quartz, chlorite, sericite and porphyroblastic carbonate. Plagioclase phenocrysts have been albitised and ferromagnesian grains largely replaced by quartz and carbonate.

378187 TS

Summary: Strongly altered, porphyritic intermediate to felsic volcanic rock, perhaps representing a lava. There is no textural evidence for the sample to represent a clastic rock, e.g. epiclastic sandstone. The original rock contained a few phenocrysts of feldspar (probably plagioclase) and a ferromagnesian phase, plus a little FeTi oxide, set in a fine grained, perhaps glassy, quartzofeldspathic groundmass. The latter might contain possible spheroidal devitrification structures. Feldspar and ferromagnesian phenocrysts have been replaced by sericite and quartz, with groundmass material having recrystallised to an assemblage of K-feldspar, quartz, sericite and minor hematite. In places, quartz aggregates form cores to the spheroidal structures. The altered rock has been cut by a few extensional quartz-rich veins containing a few aggregates of sericite. These veins might also have hosted aggregates of pyrite, but the latter has been replaced by goethite as a result of weathering.

Handspecimen: The sample is composed of a relatively massive, dark grey, fine grained, apparently rather siliceous rock. In places, possible granular texture is evident, with slightly darker and lighter "spots" up to 1 mm across. The rock could represent a fine to medium grained low grade metamorphosed sedimentary type or quartzofeldspathic volcanic type. Staining of the section offcut with sodium cobaltinitrite indicated that there is a moderate amount of K-feldspar present. The rock has been cut by a few sub-planar quartz veins up to 2 mm wide in which there are a few goethite aggregates, perhaps the weathering product of former pyrite. The sample is very weakly magnetic, with susceptibility up to 25×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, it is apparent that there is moderate preservation of relict porphyritic texture, with scattered altered phenocrysts in an altered and recrystallised fine grained groundmass. There is no diagnostic evidence for any clastic texture and hence the rock is not considered to represent a sandstone. It is likely that the original rock contained a few tabular feldspar phenocrysts (e.g. plagioclase) up to 2 mm across as well as a few smaller phenocrysts of a ferromagnesian phase (e.g. pyroxene) up to 1 mm across. Small grains of FeTi oxide are also present, commonly associated with the ferromagnesian pseudomorphs. The remainder of the rock (about 90 volume %) represents altered groundmass material, originally of quartzofeldspathic composition, but containing a few small grains of feldspar, ferromagnesian material and FeTi oxide. In the groundmass there might be one or two quartz-filled amygdules up to 1 mm across. It is possible that the groundmass was originally glassy as there are numerous diffuse spheroidal structures up to 1 mm across that might have been devitrification aggregates. From the relict texture, it is interpreted that the rock was a former fine grained, porphyritic intermediate to felsic volcanic, perhaps a lava. There is no evidence that the rock represents an epiclastic sandstone.

b) Alteration and structure: The volcanic rock has undergone strong and pervasive alteration, as well as veining. These features could be due to hydrothermal alteration. There has been complete replacement of all feldspar phenocrysts, with replacement by fine grained sericite and minor quartz. All ferromagnesian material has been replaced by quartz \pm sericite \pm hematite and most igneous FeTi oxide has been replaced by hematite. All groundmass material has been replaced and finely recrystallised to K-feldspar, quartz and sericite (commonly in aggregates), with minor hematite. Quartz aggregates commonly form cores to the spheroidal structures and the latter are diffusely outlined by finely granular hematite. The altered rock has been cut by a few extensional sub-planar veins up to 1.5 mm wide. The veins are dominated by medium grained quartz, but also contain a few aggregates of sericite, and in places, aggregates of goethite. The last phase has probably formed from the weathering of previous aggregates of pyrite. Goethite also forms staining, especially of sericite aggregates. The alteration assemblage in the sample is probably of phyllic type, but could be transitional to potassic type.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There is minor fine grained hematite throughout.

Mineral Mode: Approximate modal proportions are: quartz 50%, sericite 25% K-feldspar 20%, hematite 4%, goethite 1% and a trace of FeTi oxide.

Interpretation and Comments: It is interpreted that the sample is a strongly altered, porphyritic intermediate to felsic volcanic rock, perhaps representing a lava. There is no textural evidence for the sample to represent a clastic rock, e.g. epiclastic sandstone. The original rock contained a few phenocrysts of feldspar (probably plagioclase) and a ferromagnesian phase, plus a little FeTi oxide, set in a fine grained, perhaps glassy, quartzofeldspathic groundmass. The latter might contain possible spheroidal devitrification structures. Feldspar and ferromagnesian phenocrysts have been replaced by sericite and quartz, with groundmass material having recrystallised to an assemblage of K-feldspar, quartz, sericite and minor hematite. In places, quartz aggregates form cores to the spheroidal structures. The altered rock has been cut by a few extensional quartz-rich veins containing a few aggregates of sericite. These veins might also have hosted aggregates of pyrite, but the latter has been replaced by goethite as a result of weathering.

378188 TS

Summary: Strongly altered, medium grained lithic sandstone. The rock is dominated by finely recrystallised lithic detrital grains (mostly fine grained sedimentary material such as siliceous argillite and minor chert, but with a few possible altered volcanic lithics). There is a minor population of detrital quartz grains. The rock has undergone phyllic alteration, with strong replacement of finer matrix material and possible volcanic lithic grains by sericite and minor quartz. There has also been slight development of quartz-rich aggregates and veinlets. The rock may have contained a few grains of pyrite as part of the alteration assemblage, but pyrite has since been replaced by goethite as a result of weathering.

Handspecimen: The sample is composed of a relatively massive, fine to medium grained, pale brown sedimentary rock. It has a clastic, granular texture and appears to be a rather quartz-rich sandstone. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. Slight weathering has occurred, leading to local goethite staining. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, medium grained clastic texture is moderately preserved, although there has been strong alteration imposed. Apparent detrital grains are angular to sub-rounded and up to 2 mm across, although most are <0.5 mm across. They comprise about 50-60 volume % of the sample and are enclosed by a finer grained altered and recrystallised clastic matrix. The majority of detrital grains are lithics, with a small population of quartz grains up to 0.3 mm across. Lithic grains are dominated by fine grained sedimentary material, probably siliceous argillite (e.g. fine grained quartz and minor sericite), although some are probably finely recrystallised chert. A few lithic grains may represent altered volcanic material and are totally altered to fine grained sericite. The sample is interpreted to represent a medium grained lithic sandstone, in which the lithic detritus is dominantly from a fine grained sedimentary source.

b) Alteration and structure: There has been strong and pervasive alteration that is consistent with phyllic type. It could be a result of hydrothermal processes. Finer grained matrix material has been recrystallised to a fine grained assemblage of sericite and lesser amounts of quartz, with traces of leucoxene and possible pseudomorphs after pyrite. Within the altered matrix, sericite commonly forms irregular aggregates up to 0.5 mm across. It is possible that most of the lithic grains have been finely recrystallised, with the possible volcanic-derived lithics having been completely replaced by fine grained sericite. The altered rock also displays one or two irregular veinlike patches of fine grained quartz. Pyrite may have formed rare grains as part of the alteration assemblage but has since been replaced by goethite as a result of imposed weathering effects. Elsewhere in the sample, there is also a little goethite staining.

c) Mineragraphy and paragenesis: The sample may have had a few grains of pyrite up to 0.2 mm across, form as part of the alteration process. Pyrite has since been replaced by goethite.

Mineral Mode: Approximate modal proportions are: quartz 75%, sericite 24%, goethite 1% and a trace of leucoxene.

Interpretation and Comments: It is interpreted that the sample represents a medium grained lithic sandstone that has undergone strong phyllic alteration. The rock is dominated by finely recrystallised lithic detrital grains (mostly fine grained sedimentary material such as siliceous argillite and minor chert, but with a few possible altered volcanic lithics). There is a minor population of detrital quartz grains. Alteration has caused strong replacement of finer matrix material and possible volcanic lithic grains by sericite and minor quartz. There has also been slight development of quartz-rich aggregates and veinlets. The rock may have contained a few grains of pyrite as part of the alteration assemblage, but pyrite has since been replaced by goethite as a result of weathering.

378189 TS

Summary: Coarse grained lithic sandstone, grading to conglomerate (or could be termed a sedimentary breccia), with abundant fine grained sedimentary lithic clasts (finely recrystallised chert and siliceous argillite), cemented by fine grained hematite and minor fine to medium grained crystalline quartz. There is no evidence that the hematite has replaced former pyrite or Fe-bearing carbonate. Subsequent to hematite deposition, there has been minor veining by carbonate. The sample differs from 378109 in the fact that it contains less diversity in lithic grains, has essentially no individual detrital mineral grains and has abundant hematite cement.

Handspecimen: The sample is composed of a dark red-brown, hematite cemented coarse grained sandstone, grading to conglomerate. There are scattered angular to sub-rounded clasts up to 1.5 cm across, plus many smaller grains (typically <5 mm across) of pale brown to dark red-brown fine grained cherty or siliceous argillite composition, enclosed in a fine grained matrix of hematite. The rock is relatively massive, but very inequigranular and displays no bedding laminations. Testing of the section offcut with sodium cobaltinitrite did not reveal the presence of K-feldspar. The sample is very weakly magnetic, with susceptibility up to 30×10^{-5} SI units.

Petrographic Section:

a) Primary mineralogy and textures: In the section, it is evident that the rock is a coarse sedimentary clastic type, with rather tightly packed angular to sub-rounded clasts up to 1.5 cm across, although most clasts are <5 mm across. Most clasts are composed of massive, fine grained, recrystallised chert (i.e. dominated by finely recrystallised, relatively equigranular quartz), but a minority of clasts are composed of weakly laminated and/or foliated siliceous argillite. The latter have fine grained detrital grain texture and contain a minor amount of sericite; one or two also contain tiny recrystallised radiolarians. In-between the clasts, there is very little matrix (maybe some fine grained clasts), but there is about 20-30 volume % of cement. The latter is dominated by fine grained hematite, with later infilling by fine to medium grained crystalline quartz. The rock is interpreted to be a hematite-cemented and impregnated coarse grained lithic sandstone, grading to conglomerate. It could also be termed a sedimentary breccia. The clasts are entirely composed of fine grained sedimentary material.

b) Alteration and structure: The rock has undergone probable diagenetic cementation under oxidising conditions. Fine grained hematite has partly infilled between clasts and also impregnated and partly replaced many clasts. Later infilling between clasts has been by fine to medium grained crystalline quartz. There is no evidence that the hematite formed by weathering (e.g. of former interstitial pyrite or Fe-bearing carbonate). Subsequently, there has been emplacement of a few anastomosing veins of carbonate up to 0.3 mm across, that cut across hematite aggregates.

c) Mineragraphy and paragenesis: No sulphides have been observed in the sample. There is abundant fine grained hematite as cement and impregnation of lithic clasts.

Mineral Mode: Approximate modal proportions are: quartz 80%, hematite 15%, sericite and carbonate each 1%.

Interpretation and Comments: It is interpreted that the sample is a coarse grained lithic sandstone, grading to conglomerate (or could be termed a sedimentary breccia), with abundant fine grained sedimentary lithic clasts (finely recrystallised chert and siliceous argillite), cemented by fine grained hematite and minor fine to medium grained crystalline quartz. There is no evidence that the hematite has replaced former pyrite or Fe-bearing carbonate. Subsequent to hematite deposition, there has been minor veining by carbonate. The sample may have vague similarities with sample 378109, but differs in containing much less diversity in lithic grains and having essentially no individual detrital mineral grains (e.g.

378109 contains significant detrital quartz grains). Likewise, 378109 does not contain nearly as much hematite.