MATERIALS AND PROPERTIES SUMMARY (Basic data on maps)

MATERIAL / PROPERTIES	HARD		ROCK		TYPES		SOFT	ROCK	TYPES
	CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5	CLASS 6	CLASS 7	CLASS 8	CLASS 9
ROCK: Description	Dolerite, massive basalt. May be variable ground but always hard, often strongly jointed. Weathering may be very variable both in depth and lateral extent as well as state. Fine-grained or acidic dolerite is most highly subject to weathering.	Limestone, often impure and with thin clay bands.	Coarse siltstone and fine sandstone with occasional thin conglomerates. Uniform lithology well jointed. Includes some fossiliferous mudstone. Subject to uniform and usually shallow weathering. Fretting is common.	Predominantly well sorted quartz sandstone with some mudstone and shale. ss grain size (0.15-1.5 mm). These rocks contain a little feldspar, mica and graphite. Mudstone members are very susceptible to weathering. The sandstones have thick but gradational weathering profiles after sharp soil transition.	Mudstone and variably grained sandstone with a high proportion of rock fragments, feldspar and dark minerals. Coal bearing. Weathers deeply to clay pugs. Very limited occurrence.	Volcanic materials. Includes tuffs and breccias (rare), bubbly basalt scoria and pumice. Massive basalt flows excluded. All related to volcano vent. Weathering may be extreme and variable.	Interbedded sandstone and claystone, often sandy clays. Sandstones medium- to fine-grained (0.5-1.5 mm). Claystone very pure clay. Weathering as such is slight, but erosional effects are common.	Talus, scree, boulder beds. Talus (with soil and fines) is common on steep slopes of rocks of classes 1, 2, 3. Scree fields commonly related to class 1. Boulder beds common at river base in alluvial flats. Weathering generally insignificant.	Sand, usually windblown and beach/dune derived. A further source may be decomposition of sandstones of class 4.
SOIL: Unified class Liquid limit (%) } oven Plasticity index (%) } dry Linear shrinkage (%) } 50°C % passing 200# sieve Thickness (m)	CH 50-80 (~50-60 norm) 27-50 (~30-40 norm) 14-23 (~20 norm) 55-77 (64 av.) 0-<1 av.	- - - - - 0-<1 av.	CL-ML/CH 21-68 (~25-30 norm) 3-49 (~14-18 norm) 1-17 (~4 norm) 50-94 (68.5 av.) 0-<2 av.	SP CH-L non 35-51 plastic 21-40 2-11 ~10 norm 6-10 50-80 0-5+ av.	- - - - - 0-5+ av.	CH-CL 43-58 25-33 13-16 50-80 0-2+ av.	CH-MH 24-60 (~55 norm) 6-40 (~22-30 norm) 4-15 60-90 Intermediate	Heterogeneous - - - - 0-<1 av.	SP-SM Non plastic - - <10 None, to intermediate
GRANULAR POROSITY (%) BORE YIELD (l/h) PERMEABILITY (m/y) STORAGE COEFFICIENT ($\times10^{-5}$) TRANSMISSIBILITY (l/day/m) GROUNDWATER QUALITY (TDS ppm)	0 100-3500 0-200 - - 500-1000 (<800 av.)	<5 900-3600 - - - -	17+ (w) 8 (unw) 900-3600 0-200 - - 100-2000 (<1000 av.)	>15-20 100-2500 - ~1 1800 100-5000 (~1500 av.)	- 50-2000 - ~1 - 150-1500 (~1000 av.)	0-25 (est.) 100-20000 - - - -	C.20 100-40000 0-400 - 3000-30000 1000-5000 (>2000 av.)	- 1000-50000 - - - -	4-27 100-10000 (est.) - - - -
ROCK CEMENTING JOINT FILLING XX JOINT FREQUENCY (per horiz. m) TYPICAL BED THICKNESS (m)	- Calcite ($CaCO_3$), chloritic clays, various iron oxides <4-5 -	Calcite Calcite, clay <4 0.2	Usually clay, but sometimes siderite ($FeCO_3$) Pyrite (FeS_2) when fresh or iron oxides <4 ~0.3	Clay, often calcite. May be replaced by silica (SiO_2). Sometimes clay <1-2 ~0.05 (md.), ~1-2 (ss)	Clays Sometimes clay <1-2 ~0.05 (md.), ~1-2 (ss)	Commonly clay Usually clay - -	Rarely cemented - - 0.10 (clays)	Clay or mud - - -	Rarely cemented - - -
DENSITY (g/cm^3) ★ APPARENT RESISTIVITY (ohm-m) LONGIT. VELOCITY V_1 (m/s) ★★ TRANSVERSE VELOCITY V_2 (m/s) POISSON'S RADIO σ YOUNGS MODULUS E ($\times10^{10}$ Pa) BULK MODULUS K ($\times10^{10}$ Pa) RIGIDITY MODULUS G ($\times10^{10}$ Pa) UNIAXIAL COMPRESSIVE STRENGTH ($\times10^6$ kg/m^2) x10 for MPa	2.80-3.10 10-100 (w) 100->5000 (unw) 1700-2500 (w) 3000-7000 (unw) 1500-2000 (w) 3000-4000 (unw) 0.02-0.1 (w) 0.3-0.4 (unw) 1-4 (w) 9-11 (unw) 0.5-3 (w) 9-10 (unw) 1-5 (unw) 40 (unw)	2.64 100-5000 1000-2000 3000-5000 2000-3000 0.2-0.4 3-6 1-5 1-1.5 20	2.20+ (w) 2.52-2.60 (unw) 100-1000 (dry) 10-100 (wet) 1200-2500 3000-5000 2000-3000 0.2-0.4 1-4 2-4 0.6-1.2 15	2.37 av. (ss) 2.49 av. (md) 5-1000 1000-2000 3000-4000 1500-2000 0.04-0.7 2-3 1-3 0.8-1.1 9 (ss), 6 (md)	2.43 av. (ss) 2.51 av. (md) 10-100 1000-2000 2500-3500 1500-2000 0.05-0.3 2 0.8-1.1 0.8-1.1 8 (ss), 6 (md)	2.00-2.40 10-1000 500-1500 2000-3500 1500-2000 0.05-0.25 - - - Variable	1.90-2.10 2.50 1600-1800 1500-1700 Non elastic, negative -0.3 0.65 0.1 0.5 1	- 10-500 900-1600 - - - - - Intermediate	- 10-1000 (wet) 500-1500 - - - - - -
FRESH ROCK EXCAVATION		Explosives	and/or	hammering		Variable. Sometimes rippable.	Ripping	and	blade work

HOBART ENGINEERING GEOLOGY MAP SERIES

by D.E.LEAMAN B.Sc., Ph.D.

I. G. SYMONS
Director of Mines

In hard rock types permeability is proportional to joint frequency and joint openness as the solid material is for all practical purposes impermeable (classes 2, 3, 1, 6). In the case of classes 4, 5 the permeability depends on the above properties but locally in sandstone sequences it may be controlled by intergranular porosity permeability. In soft rock types it is directly proportional to interconnected pore space availability.

Joint frequency may be affected by rock type. For example the igneous rocks of classes 1, 6 have a chilled margin in which frequency may exceed 15-20 per metre. Sedimentary rocks heat affected (thermally metamorphosed by such rocks) may have comparable frequencies. The figures quoted are general for rock away from disturbing sources. The joint frequency is also increased near faults.

* Densities quoted are bulk wet densities.

** Seismic velocities are affected by the weathering state of the rock and this variation is indicated. However they may also be a range of velocities in fresh rock depending on the intensity of fracturing or jointing. For example, solid dolerite with a few calcite-sealed joints will have a velocity in excess of 6,000 m/sec (V_1). Strongly jointed dolerite perhaps with a few open joints as well, will show a velocity as low as 4,000 m/sec (V_1). Thus the actual base velocity gives an indication of the overall physical state of the rock. Asymmetry of velocities in two directions will reflect the joint intensities in those directions.

xx The comment on joint filling is only applicable to fresh, unweathered rock. Upon weathering oxidation and removal of the seal occurs. In classes 1, 6 this may result in a porous filling of iron oxides and in classes 2, 5 a new seal of clay. On weathering of class 3 joints tend to remain open.

Class 2 and 3 materials tend to be brittle and well jointed and hence easily worked by use of explosives and hammers followed by ripping. Small trenches need use of both explosives and hammer methods. Classes 4 and 5 sandstones are not brittle and very tenacious and wise use of explosives is needed to attack rock weaknesses. Hammering is often more effective in small scale workings. The associated mudstones are friable and easily excavated. Classes 1 and 6 are effectively treated with explosives. Hammering is not recommended. Classes 7, 9 are dozeable but class 8 may need a combination of methods depending on situation and scale of boulders. All above comments apply to fresh rock, and similar comments apply to weathered rock of classes 2, 3, 4, 5. The degree of weathering is more important in the case of classes 1, 6 (1 especially) and sometimes this material will be rippable. The seismic velocity is a good indication. (see table under geophysical methods).

ENGINEERING IMPORTANCE OF GEOLOGICAL FEATURES

ROCK BOUNDARIES

Normal: Rocks of classes 2, 3, 4, 5 and 6 usually overlie each other in a regular, tabular manner. Rocks of classes 1, 7, 8 and 9 may have irregular boundaries with other classes and sometimes with each other. In each case full details on thickness, overlain material and the nature of boundary is given on the map overlay.

Faulted: Faulting increases the fracturing and joint intensity of the rock and hence weakens it. In the case of rock classes 1 and 3 especially this means an increase in permeability and seepages would be common. Rock of classes 2, 4, 5, 6 tends to weather deeply very quickly in zones of high joint intensity which may result in confined water situations and a very puggy fault zone. Some drainage is usually necessary in such zones.

As a result of the possible weakness of fault-zone material the width should always be determined and foundation requirements calculated to provide support across the zone. If this is not done differential compaction may occur in that part over the fault - especially if rock classes 2, 4, 5 and 6 are involved.

If rock class 7 is involved on only one side of a fault special care will be needed in loading the site in order that significant compaction, with rupture of the construction, does not occur. In each case the natural loading on class 7 has been indicated.

Many of the smaller faults have been omitted from the map, or not even located. The major faults (F*) will present problems of one kind or another and it should be appreciated that there is a risk, however slight in seismically quiet Tasmania, in building on such a fault. The width of fault zones is dependent on rock type and type of faults and is consequently very variable. Observations are indicated on the map.

WEATHERING COVER

Weathering is of little concern in rock classes 2, 3 and usually 4, but rocks of classes 5 and 6 (especially 1 and 6) may weather irregularly. In the Hobart area the depth of weathering is usually only a very few metres and foundations should always be excavated to fresh rock or rock of acceptable stability. Rocks of class 5 may be deeply weathered and an even loading should be ensured or piles driven to rock.

JOINT DIRECTIONS

Many of the principal joint directions in a number of locations have been indicated. As jointing may be very irregular and variable from place to place this information should be taken as an indication for the immediate vicinity only. Excavation can be simplified by recording the (usually 2) main directions in the locality and using them as parting directions. Design orientation in accord with such directions may prevent block collapses. Rock falls are rare generally but oversteep slopes in well jointed rocks are to be avoided.

DIP OF BEDDING

Normally dips in the Hobart region are not great enough to cause any problems. However, locally about Mt Faulkner and Richmond, slippage of whole blocks is possible upon excavation or if cuttings are made. The danger situation occurs when the dips exceed 10-20° out from the hillslope. A considerable water problem may also be encountered in this situation.

VOLCANIC NECKS

The materials about necks are very variable. The only normal tuffs and breccias in the area are to be found in this situation. A neck is usually made up of a single solid basalt core with more porous basalt in flow form with interbedded tuffs about it. A careful foundation study for a large structure on such features is necessary due to this variability.

LIMESTONES

Two rather impure limestone formations are not known to give rise to sink-holes or caverns since they are impure and occur at stratigraphically low levels. They only crop out where major faulting has occurred, as near Mt Faulkner.

SOILS

Soils are generally very thin except where shown on the map. As a result few soil mechanics problems arise. Soil properties as observed in selected locations are listed. Problems of landslides, and those applicable to rocks of classes 7, 8, 9 are treated below.

BEDDING THICKNESS

Bedding may affect bulk permeability, facility of splitting and possible stability. Rock classes 2 and 3 have a small regular bedding thickness but classes 4 and 5 may have variable bedding. Collapse blocks are usually very small with the possible exception of some rocks (ss) of class 4.

LANDSLIPS

Are not a major problem for the following reasons:

(1) Rainfall is generally of low intensity, (2) Materials liable to slippage are either not in dangerous topographic situations or are remote from built-up zones or work projects. (potential slip material and locations are indicated on the map), (3) Thin soils, (4) Flat-lying rocks (refer dip of bedding).

The potentially dangerous materials are in classes 7, 8, 9. Class 7 materials are not a problem generally because they occur in areas of low relief except at Taroona where caution should be exercised. Similar comments apply for rocks of class 9. Most major slips that have occurred are at a high altitude and on steep slopes in material class 8. Boulder beds, talus and scree have high porosity and permeability, are poorly sorted and usually clay rich. They are capable of mass movement when wet. Cuttings should be low-angle and well drained by cutting a deep ditch upslope. Minor slips occur when thick soils are present and are normally restricted to road cuttings and steep ditches. They are rare in natural situations. In each case a low-angle well drained cut is essential.

ROCKS OF CLASSES 7, 8 AND 9

Each type of material is subject to compaction and settling under load. Class 7, and 9 where thick, will compact uniformly provided loadings are balanced and well spread. Class 7 usually occurs in basins which have been subject to some erosion and unloading. In each case an indication of material removed is given. Loadings in excess of that removed will induce settling which will stabilise and cause no further problems provided the load is balanced. Class 8 materials are much more unpredictable and especial care and advice is recommended for each case where a slope is involved. In flat areas the above comments apply.

WATER PROBLEMS

Seepages and springs may initiate slides or cause undermining of structures. Only a few of the springs occurring within the region are indicated but an examination of the location of those shown, as at boundaries and other discontinuities, will give a suggestion on likely occurrence. Most seepages are very small delivering less than 100-200 litres/hour. Water quality may be such that corrosion of pipes and cables occurs. Generally the only bad waters are to be found in class 7 materials, especially around Pitt Water. The problem has not arisen often because of shallow laying of pipes and relatively deep water tables.

SURFACE MANIFESTATION OF ROCK CLASSES

Solid rock of class 1 produces convex slopes with local roughness up to 2 m high, and where relief is high cliffs up to 100 m. Low lying smooth areas are rare. Not normally trafficable.

Classes 2 and 3 produce steep, generally convexo-concave smoothly contoured slopes in low relief. Cliffs become important and dominant with increasing local relief. Thick vertical sequences are typically benched in 5 to 10 m convex-concave steeps. Limited trafficability.

Class 6 is not extensive and locally smooth. Rarely topographically distinctive. Trafficable.

Class 7 shows smooth and flat or very gentle slopes. Low lying, extensive and trafficable when dry. Class 8 produces constant or concave slopes at >25°. Locally rough (1 m) or very rough (3 m). Constant relation to source of material moving from high ground. Not extensive and untrafficable.

Class 9 is usually smoothly contoured but may be steep where active or fossil dunes exist. Locally smooth but untrafficable where steep or loose.

SHRINKAGE AND SETTLEMENT OF SOILS

All the soils in this region will, under load, settle slightly. This means that paths and surface structures may need reinforcement or be constructed of flexible materials.

Soils of classes 1, 2, 3, (5), 6 and 7 are also subject to strong seasonal shrinkage/expansion depending on contained water. This effect is most pronounced in the clay soils on, or derived from, classes 1 and 7.

STABILITY OF CUTS

With the exception of materials of class 8 all rock materials which are not actively weathering (soils) show a high degree of stability when exposed in cut lines, trenches or tunnels. Soil and soft weathered rock of all classes should be scraped from the top of the cut faces. The following comments apply to firm weathered on unweathered material.

Materials of classes 2 and 3 are normally very stable even in vertical cuts. In cuts near faults where there is a high joint frequency, block falls on a small scale are likely on exposure to weathering or to running water. In such situations step-cutting is recommended with a step height of 5-8 m and step depth of 2-3 m. Vertical cuttings greater than 10 m without stepping may be very dangerous.

Materials of classes 4 and 5 are stable when freshly cut. The sandstones of both classes remain stable in any cut whereas the mudstones weather differentially and slip from the face. If the proportion of sandstone to mudstone exceeds 1:1 even vertical cuts are usually stable although the cut will not maintain a planar face. Where there is a high proportion of mudstone, step-cutting will be necessary with step parameters as recommended for jointed rock of classes 2 and 3.

Cuttings in class 1 material should never be greater than 60°, unless shallow, nor higher than 10-15 m without stepping. The step width should be 2-4 m depending on the joint frequency. Large blocks often fall from dolerite cuttings. Due to the variability of jointing this material lacks the stability of bedded rocks. Fragmental falls are common on dolerite faces, especially after some exposure to weather and following heavy rains.

Due to the variability of class 6 materials it is not possible to specify a general treatment. Great care will be necessary in establishing a safe slope (*e.g.* Summerleas, Southern Outlet Road).

Cuttings in class 7 materials should not be deep nor too steep since these materials are very easily eroded and in the appropriate circumstances subject to slip failure. Deep cuttings in such materials are unlikely to be required in the Hobart area. However cuttings over 4-5 m deep should be carefully drained and may need some support.

Class 8 materials are very unstable. Deep cuttings should be avoided if possible. All cuttings should be of low angle (less than 45-50°), stepped if greater than 5-6 m high with step depths of 2-3 m. The cut must be well drained and substantial surface flows must never be allowed to reach the cut. Failure is certain in such an eventuality.

In the case of cuts in classes 2-5 account must also be taken of the dip of the materials. On that side of the cut where the dip is into the excavation the slope of the face will need to be less and stepped more often than on the opposing face. In jointed rocks allowance must also be made of the attitude and dip of joints as these properties will control the size of blocks dropping from the face and the scale of the slippage as a whole.

USE OF GEOPHYSICAL CRITERIA AND METHODS

SEISMIC METHODS

Seismic methods make use of velocities of elastic wave transmission in the material. Low seismic velocities reflect low density, poor packing and general lack of solidity. As mentioned under note** the velocity will vary in weathered rock according to the degree of weathering and in unweathered rock according to the intensity of fracturing. The table below summarises the workability of the materials with respect to seismic velocities. The method can be used to give the velocity profile which may be interpreted in terms of soil, weathering thickness and state of fresh and weathered rock. It is also possible, if sufficient and appropriate geophones are available, to determine the in situ measures of E, K, G and σ.

ELECTRICAL METHODS (GALVANIC RESISTIVITY)

Electrical methods make use of conductivity differences of the materials. These methods can be used to determine depth of water table, width of fault zones as well as thickness of soils and weathering, but does not give as good an indication of rock character as the seismic methods. It has the advantage of still giving results where the seismic methods fail, *e.g.* where high velocity material overlies low velocity material.

MAGNETIC METHODS

Magnetic methods are especially useful in dealing with classes 1 and 6. They can be used to locate zones of more solid material and to pick out trenches of weathering.

GRAVITY METHODS

In certain situations gravity methods can be used to locate faults, and the thickness of class 7-9 materials where this exceeds 10 m. Such methods are rarely used in engineering work because seismic methods are more useful for obtaining near-surface information.

USE OF MATERIALS

Class 1. When fresh and free from accessory clays and chlorite minerals they make excellent fill, dam wall/rock fill, and road surfacing. They also make excellent concrete aggregate. When weathered they can be used in road foundations. Coarse-grained material weathers to a coarse gravelly aggregate which is highly regarded for gravel road surfacing.

Class 2. The limestones are not pure enough to be used economically for cement manufacture. However the various mudstones, siltstones are suitable for road base use and bind well when crushed and wet.

Class 3. Makes excellent fill and binds well for road foundation use.

Class 4. Sandstone is suitable for building stone use. Mudstone is unsuitable for any type of construction work. Crushed fresh material and clays derived from class 4 materials may be used for brick-making.

Class 5. Unsuitable for all uses except perhaps road base material.

Class 6. When fresh may be used for road surfacing or for aggregate.

Class 7. Clays may be used in brick-making, etc.

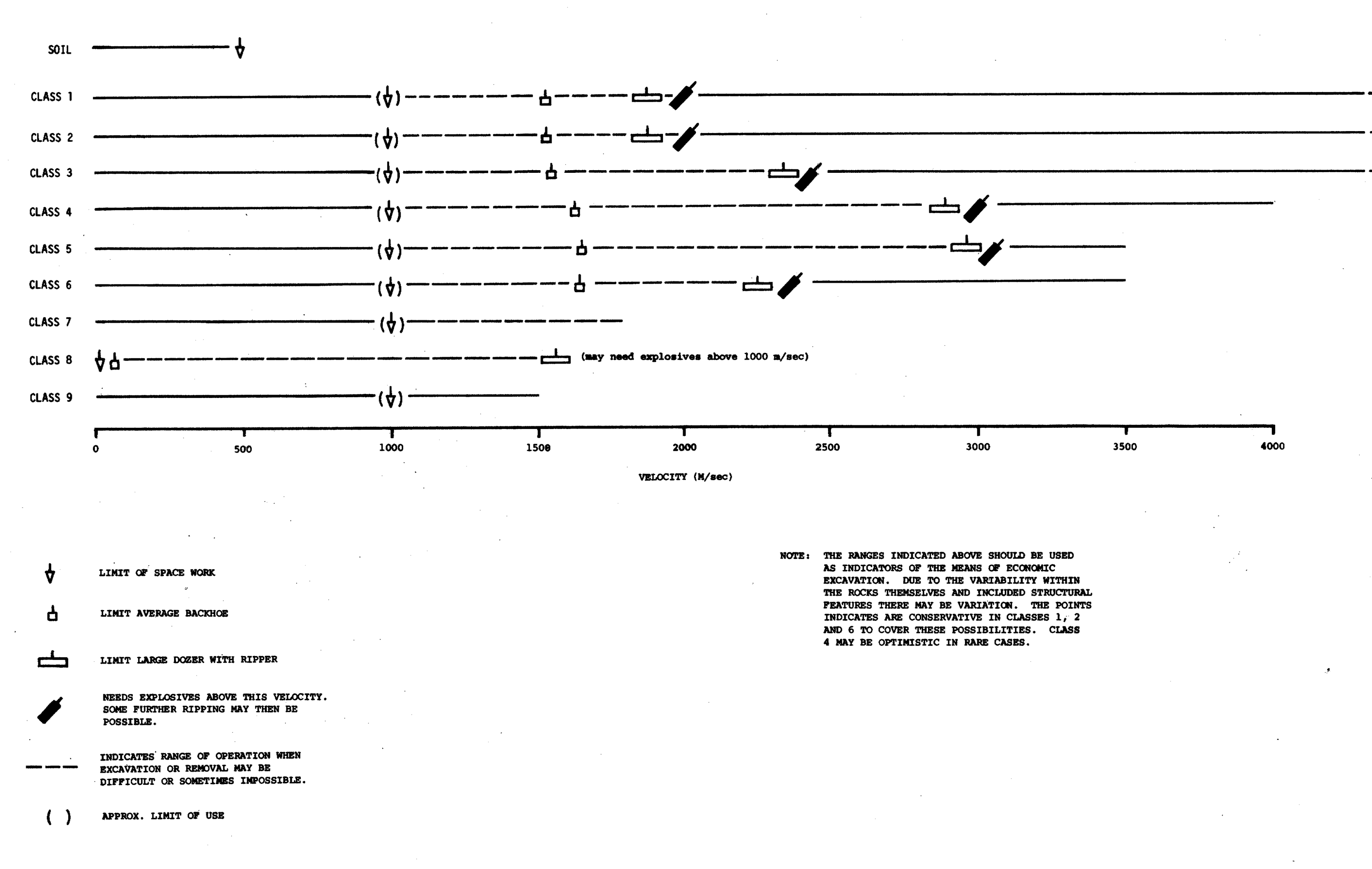
Class 8. Generally unusable if derived from dolerite. If derived from classes 2 or 3 may be used as fill and road base materials.

Class 9. Sand suitable for concrete mix and glass making.

$ The indication of a quarry and the use of which the material is, or was put is in no way to be taken as an approval of that site on asethetic or economic grounds. Least objectionable alternatives are suggested. The information is supplied as a guide to material uses.

Acknowledgements.

CHART OF WORKABILITY



NOTE: THE RANGES INDICATED ABOVE SHOULD BE USED AS INDICATORS OF THE MEANS OF ECONOMIC EXCAVATION. DUE TO THE VARIABILITY WITHIN THE ROCKS THEMSELVES AND INCLUDED STRUCTURAL FEATURES THERE MAY BE VARIATION. THE POINTS INDICATES ARE CONSERVATIVE IN CLASSES 1, 2 AND 6 TO COVER THESE POSSIBILITIES. CLASS 4 MAY BE OPTIMISTIC IN RARE CASES.