RIPPABILITY ASSESSMENT FOR THE PROPOSED OPEN PIT GOLD MINE AT GLOBE-PROGRESS, REEFTON, NEW ZEALAND

PHILIP CLARK

Department of Geological Sciences
University of Canterbury, Christchurch, New Zealand

SUMMARY

There are many methods used to predict the rippability of a site, most of which involve using a particular system to rate the rock mass. A preliminary rippability evaluation of a site may be performed by determining the seismic velocity variation within the rock mass. Seismic velocities are used as an estimate of rippability because they are influenced by geological and physical properties of the rock mass. However, a complete rippability evaluation requires rock mass and rock material characterisation as well as data on possible ripping machinery to be used. If the rock mass is rated as being very good rock, then ripping may be difficult. Likewise, if the bulldozer is underpowered, its productivity may be too low and the ripping rate will be slow.

Six seismic refraction traverse lines were surveyed at the proposed open pit gold mine at Globe-Progress, near Reefton using a single channel seismograph, then interpreted using the Generalised Reciprocal Method. Combining the seismic velocities found and data on Komatsu's D575A-2 bulldozer, it is estimated that 85% of the pit is rippable, and a further 7.5% is marginal. This means that 7.5% of the open pit area is unlikely to be rippable. However, further seismic refraction surveys, as well as a complete rock mass classification, need to be done to provide a three-dimensional site model and to clearly identify the rippable, marginal and non-rippable zones.

INTRODUCTION

Globe-Progress is located in an area of Early Ordovician turbidite sequences of alternating mudstones and sandstones, known as the Greenland Group (figure 1). In the Late Ordovician and Silurian, folding and metamorphism resulted in ore fluid generation and gold mineralisation in the Reefton area. Mining activity started at Globe-Progress in 1878, and by 1920 the ore reserves had been exhausted. By then, 418,343 ounces of gold had been extracted from 1,062,727 tons of crushed quartz at an average grade of 12.2 g/t. In the early 1980s, CRA Exploration Limited acquired exploration licences over most of the Reefton Goldfield and began a regional exploration programme that resulted in 39 holes being drilled on Globe Hill. The drilling defined an area of disseminated gold mineralisation adjacent to the quartz veins. In 1991, Macraes Mining Company Limited took over the licences for the area. They are now proposing to develop an open pit mine at Globe-Progress based on a resource of 8.94 Mt at 2.69 g/t (Barry, 1993).

To extract the overburden from the pit, either bulldozer ripping, drill and blast or a combination of the two methods will be used. To evaluate the rippability of the site, rock mass and rock material characteristics are required, as well as information on possible ripping machinery to be used.

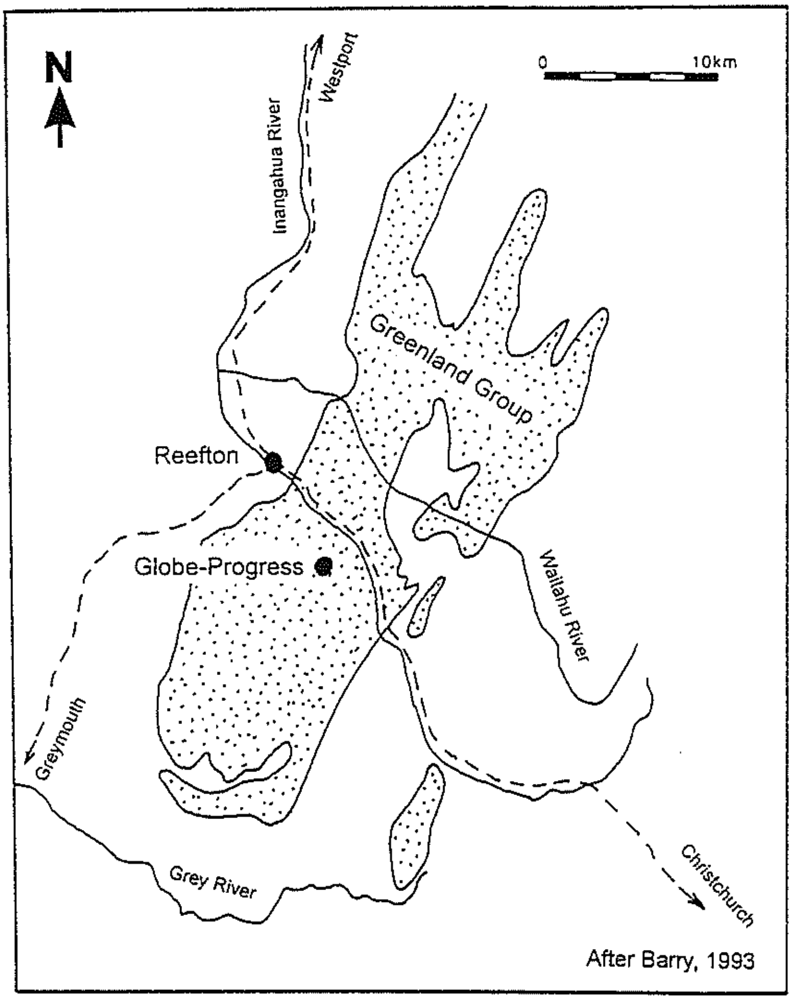


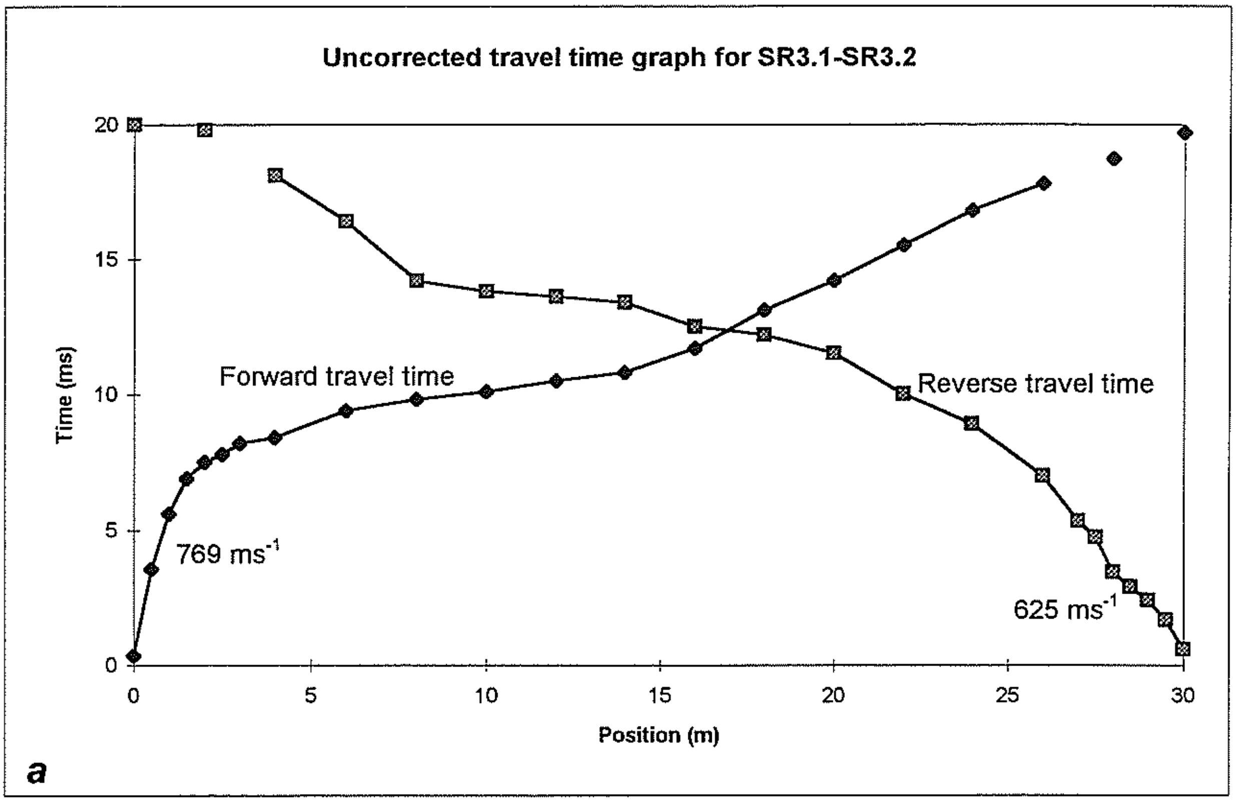
Figure 1: Location of the proposed open pit mine in Greenland Group sediments at Globe-Progress.

RIPPABILITY EVALUATION

There have been many methods produced that attempt to predict the rippability of rock. One of the first was by Weaver (1975) and is based on Bieniawski's 1973 rock mass classification. It uses Bieniawski's RMR and the seismic velocity of the rock mass. Subsequent studies have altered Weaver's method by trying to predict the productivity of the ripping bulldozer (Braybrooke, 1988; MacGregor et al, 1994; Minty and Kearns, 1983) or by correlating rippability with rock strength and discontinuity spacing rather than seismic velocity (Braybrooke, 1988; Pettifer and Fookes, 1994). The most recent study (MacGregor et al, 1994) recommends prediction of productivity and identification of locations or conditions that will be difficult to rip, and this approach seems to be the most appropriate.

Seismic velocities are used to estimate rippability because they can be related to geological and physical properties of rocks such as density, compaction, cementation, fracturing, anisotropy, mineralogy, porosity, weathering, water saturation and rock elasticity (Palmer, 1980; Weaver, 1975). However, only bulldozer manufacturers use seismic velocity alone to determine the rippability of a site. Weaver (1975) states that seismic velocities should be used to indicate possible methods of excavation and the equipment that could be used, and this approach has been followed in this situation.

A total of 307m was surveyed over six seismic refraction traverse lines using a single channel seismograph and a sledgehammer as the energy source. The Generalised Reciprocal Method was used to analyse the seismic refraction data as this method can tolerate dips in the topography or the refracting surface of up to 20°. An example of the travel time graphs along SR3.1-SR3.2 is shown



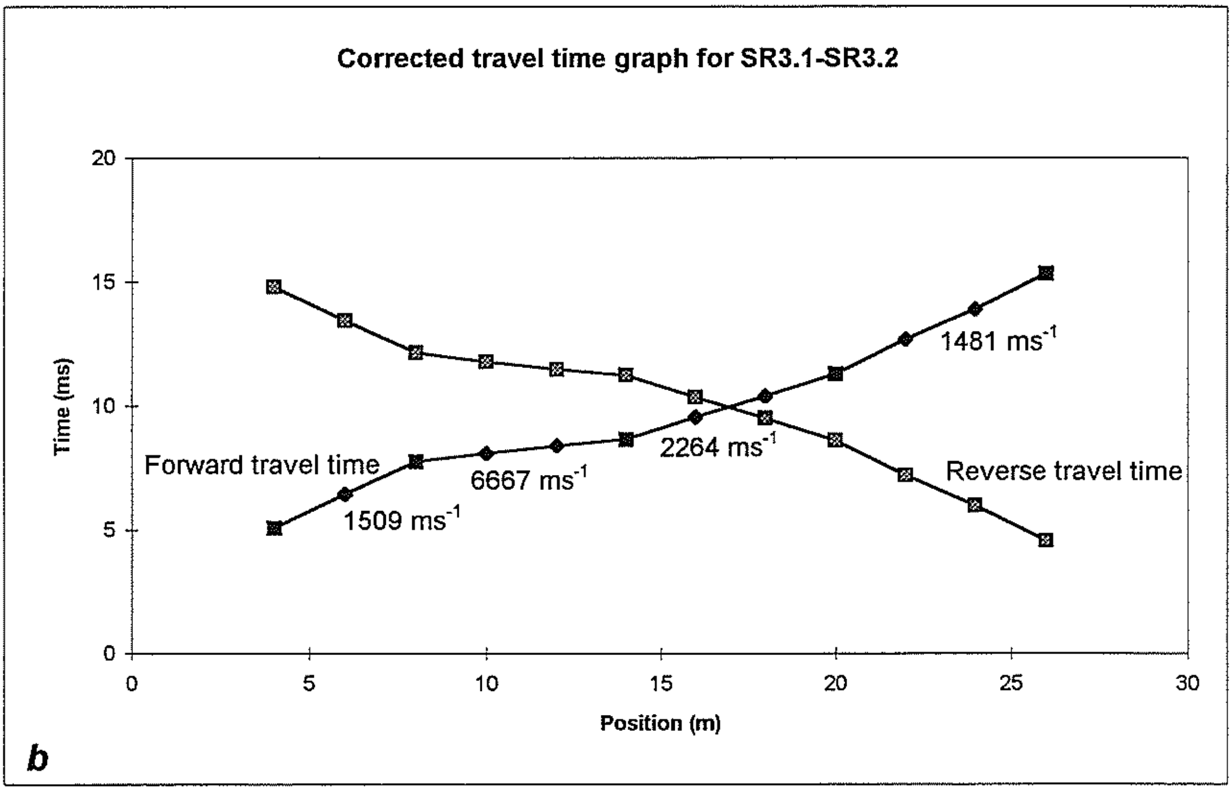


Figure 2: Uncorrected (*a*) and corrected (*b*) travel time graphs for SR3.1-SR3.2

in figure 2. The velocities were sorted into ranges of 500ms^{-1} and plotted in a normal distribution (figure 3). The data is very finely skewed, indicating that most of the velocities found are in the lower velocity zones (less than 3000 ms^{-1}). On some of the traverse lines the data are slightly scattered, which indicates the presence of defects and/or minor changes in the lithology.

Rippable, marginal and non-rippable zones for Komatsu's D575A-2 bulldozer (the bulldozer recommended by Komatsu; John, 1994) were superimposed onto the normal distribution plot to form a preliminary estimation of areas of rippable, marginal and non-rippable zones (figure 3). Approximately 85% of the velocities fit into the rippable zone - implying that 85% of the pit area will be rippable - and 92.5% of the velocities fit into the rippable and marginal zones, indicating that 7.5% of the open pit is unlikely to be rippable. However, bulldozer manufacturers tend to be overly optimistic in the rippability capabilities of their machines (Braybrooke, 1988; MacGregor et al, 1994) so the non-rippable zones may total more than 7.5 % of the proposed open pit area. An initial study undertaken by Komatsu (John, 1994) suggested that at least 80% of the open pit area was likely to be extracted at a rate of 850 Bm^3/hr and my results therefore, compare favourably with Komatsu's assessment.

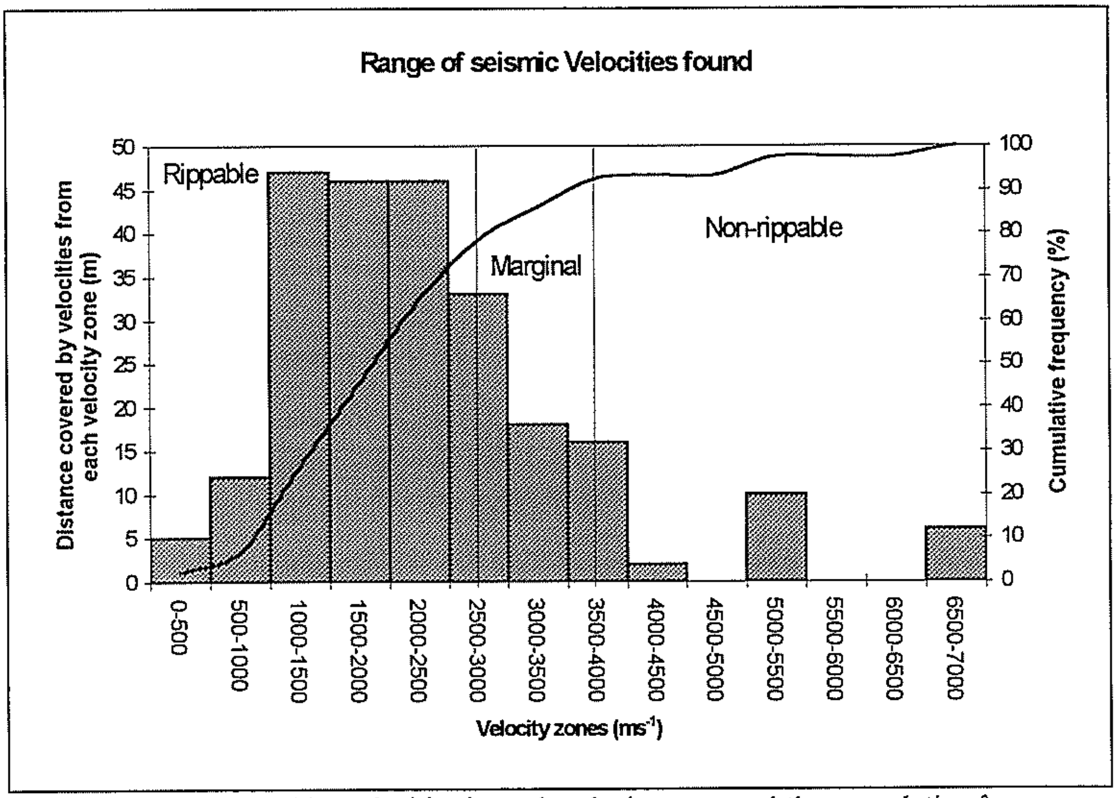


Figure 3: Distances covered by velocities in each velocity zone and the cumulative frequency. The rippable, marginal and non-rippable zones for shales, sandstones, siltstones and claystones - rock types likely to be found in the open pit area - for Komatsu's D575A-2 bulldozer are also marked (Data from John, 1994).

ROCK MASS CHARACTERISATION

Rock mass characteristics from road outcrops need to be correlated with rock mass characteristics from drill core, so that a three-dimensional geotechnical model of the open pit area can be developed. This will be done by comparing RMR values and strength determinations from road outcrops and drill core. Rock mass velocities range between 750ms^{-1} and 6650ms^{-1}, with a mean of 2300ms^{-1}, and the velocities from rock material range between 3300ms^{-1} and 4700ms^{-1}, with a mean of 4150ms^{-1}. The rock mass velocities are for massive sandstone units or for alternating sandstone and siltstone beds, while the rock material velocities are all from sandstone drill core.

Rock mass velocities are normally less than rock material velocities because of the presence of defects that may be infilled with water, air, soil or alteration products, and which reduce the average velocity of the rock mass.

Irregular lump point load testing has been performed on samples from road outcrops, and porosity and density characteristics have also been determined on selected sandstone core samples. Point load strength indices depend on the weathering of the sample and vary considerably. Unweathered rock samples yielded a mean $I_{s(50)}$ value of 5.06 MPa from 59 samples whereas slightly weathered rock samples had a mean $I_{s(50)}$ value of 2.68 MPa from 21 samples. Moderately and highly weathered samples were not tested as their strength would be expected to be minimal. Also determined from limited drill core samples are the mean dry density (2695kgm^{-3}), the mean saturated density (2710kgm^{-3}), and the mean porosity (1.30%). The density values are relatively high for sandstones, and the porosity is relatively low because the grain size is medium to fine and the rocks have a metamorphic overprint that has compacted the rock, resulting in low void (pore) volume. The implications of this are that the rock from within parts of the open pit area may be very hard to rip and may even require blasting. Therefore, more than 7.5% of the rock mass may be non-rippable.

CONCLUSIONS

- Seismic velocities can be used to estimate rippability because the seismic velocity of a rock is dependant on geological factors such as density, porosity, cementation and weathering.
- A preliminary rippability evaluation, combining seismic refraction data and data from Komatsu, indicates that it may be feasible to rip 80-85% of the rock mass from the open pit and a further 7.5% should be marginal to rip.
- A complete rippability assessment needs to use geological factors such as rock strength, hardness, weathering, density, defect spacing, defect persistence and defect orientation, which may be correlated with the productivity of the bulldozer to be used. Once this data is obtained, a complete rippability evaluation will be done and may alter the preliminary estimation presented here.

REFERENCES

Barry JM, 1993. *The History and Mineral Resources of the Reefton Goldfield,* Resource Information Report 15, Energy and Resources Division, Ministry of Commerce, 59 pages.

Beetham RD; Richards L, 1995, *Globe-Progress Mining Project. Assessment of open pit geometry,* Unpublished Report for Macraes Mining Company Limited, Reefton, 26 pages.

Bieniawski ZT, 1973, Engineering classification of jointed rock masses, *Transactions of the South African Institute of Civil Engineers,* volume 15, pages 335-344.

Braybrooke JC,1988, The state of the art of rock cuttability and rippability prediction, *Proceedings of the Fifth Australia New Zealand Conference on Geomechanics,* pages 13-42.

John I, 1994, *Site visit report, Globe Progress Development near Reefton, New Zealand,* Unpublished report for Macraes Mining Company Limited by Komatsu, 13 pages.

MacGregor F; Fell R; Mostyn GR; Hocking G; McNally G, 1994, The estimation of rock rippability, *Quarterly Journal of Engineering Geology,* volume 27, pages 123-144.

Minty EJ; Kearns GK, 1983, Rock mass workability, *In* Knight MJ; Minty EJ; Smith RB (editors) *Collected Case Studies in Engineering Geology, Hydrogeology, Environmental Geology: Geological Society of Australia Special Publication,* volume 11, pages 59-81.

Palmer D, 1980, *The Generalised Reciprocal Method of Seismic Refraction Interpretation,* Society of Exploration Geophysicists, 104 pages.

Pettifer GS; Fookes PG, 1994, A revision of the graphical method for assessing the excavatability of rock, *Quarterly Journal of Engineering Geology,* volume 27, pages 145-164.

Weaver JM, 1975, Geological factors significant in the assessment of rippability, *The Civil Engineer in South Africa,* volume 17, pages 313-316.