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Reducing Vulnerability of Pacific ACP States

SOLOMON ISLANDS TECHNICAL REPORT

ASSESSMENT OF POTENTIAL TERRESTRIAL AGGREGATE SOURCES ON GHIZO ISLAND, SOLOMON ISLANDS

May 2008



Looking west towards Gizo Township from Nusatupe Island

Prepared by:

Akuila K. Tawake

SOPAC Secretariat

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PACIFIC ISLANDS APPLIED GEOSCIENCE COMMISSION

c/o SOPAC Secretariat
Private Mail Bag
GPO, Suva
FIJI ISLANDS
http://www.sopac.org
Phone: +679 338 1377
Fax: +679 337 0040
www.sopac.org
director@sopac.org

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EXECUTIVE SUMMARY

Tawake, A. 2008. *Assessment of Potential Terrestrial Aggregate Sources on Ghizo Island, Solomon Islands.* EU EDF 8 – SOPAC Project Report 107. Pacific Islands Applied Geoscience Commission: Suva, Fiji. 34 p.

Most sand and gravel that are used for building construction on Ghizo Island are sourced from the neighbouring islands Kolobagara, Rendova, and Ranogga. The Department of Works in Ghizo sometimes also imports crushed gravel from Honiara for road works within the town area. As there had been no previous attempt to assess the potential of terrestrial aggregate sources within Ghizo Island, a request was made by the Western Provincial Administration in 2004 to do so.

Aided by a geological map of Ghizo and local field assistants, the aggregates assessment was carried out by inspecting various sites within the island where significant rock outcrops may occur. Each rock outcrop was assessed for the following parameters: quantity of exposure, quality of rock at the site, how accessible the site is, and distance to Gizo Town. Two members of the Ghizo Volcanic Formation were identified as the best available source of aggregates on the island: they are Olivine Basalt Breccia and Polymict Breccia Units that occur on the western and southern part of island, respectively.

Both breccia units were selectively sampled for geotechnical analyses by collecting rock fragments from three separate sites. Selective sampling was necessary because matrices of both breccia units were generally weathered, weak and crumbly and mostly unsuitable for the required tests.

Samples were tested in Fiji to ascertain the quality of the rocks and to determine their potential applications. Physical and mechanical tests carried out to the appropriate specifications were: Specific Gravity, Porosity, Petrography, Los Angeles (LA) Abrasion Test, Aggregates Crushing Value (ACV), Schmidt Hammer, and the Point Load Tester (PLT).

The Basaltic Breccia Unit proved not be the best material in existence, but certainly the best available source of aggregates on Ghizo Island. Both the Polymict Breccia and the Basalt Breccia Units exhibited good geotechnical behaviour and can be used for road upgrading / sealing and as construction materials once they are screened and crushed.

The higher relative abundance of rock fragments favoured the Basalt Breccia (clast to matrix ratio 70 : 30 %) over Polymict Breccia (50 : 50 %). Fresh exposures of both units, occurring along the western and southern rim of the island (between Saeragi Village and Gizo Town), can be developed to supply road and construction materials. However, the long-term supply of aggregates for building construction on Ghizo Island may require continued importing of terrestrial-derived sand and gravel from neighbouring islands.

ACKNOWLEDGEMENTS

This Project was supported by the European Union, under the EDF8 funding; the Pacific Islands Applied Geoscience Commission (SOPAC) was responsible for its implementation.

The support of the Permanent Secretary of the Department of Mines and Energy, Mr. Donn Tolia, during the 2004 reconnaissance visit and the facilitation of the 2005 site assessment is gratefully acknowledged. I thank David Natogga of the Department of Mines for his assistance during the fieldwork. Dr Jaap Jasperse edited the final draft report.

1. INTRODUCTION

The island of Ghizo is a small volcanic island located to the west of New Georgia, the biggest island in Western Province, Solomon Islands (Figure 1). Ghizo Island hosts Gizo Town, the administrative centre of the province, and reportedly the second largest urban centre in the country after the capital Honiara. A hospital, hotels, supermarkets, a wharf and the provincial office represent the township's major buildings and infrastructures.

The level of construction on the island is relatively low compared to Honiara, thus the demands for raw construction materials like sand and gravel are generally low. Local sources of aggregates are being perceived as of poor quality; consequently most sand and gravel supplies are being imported from the nearby bigger volcanic islands Kolobagara, Rendova and Ranogga. Long haulage distance leads to high importation costs, which in turn makes buying sand and gravel expensive.

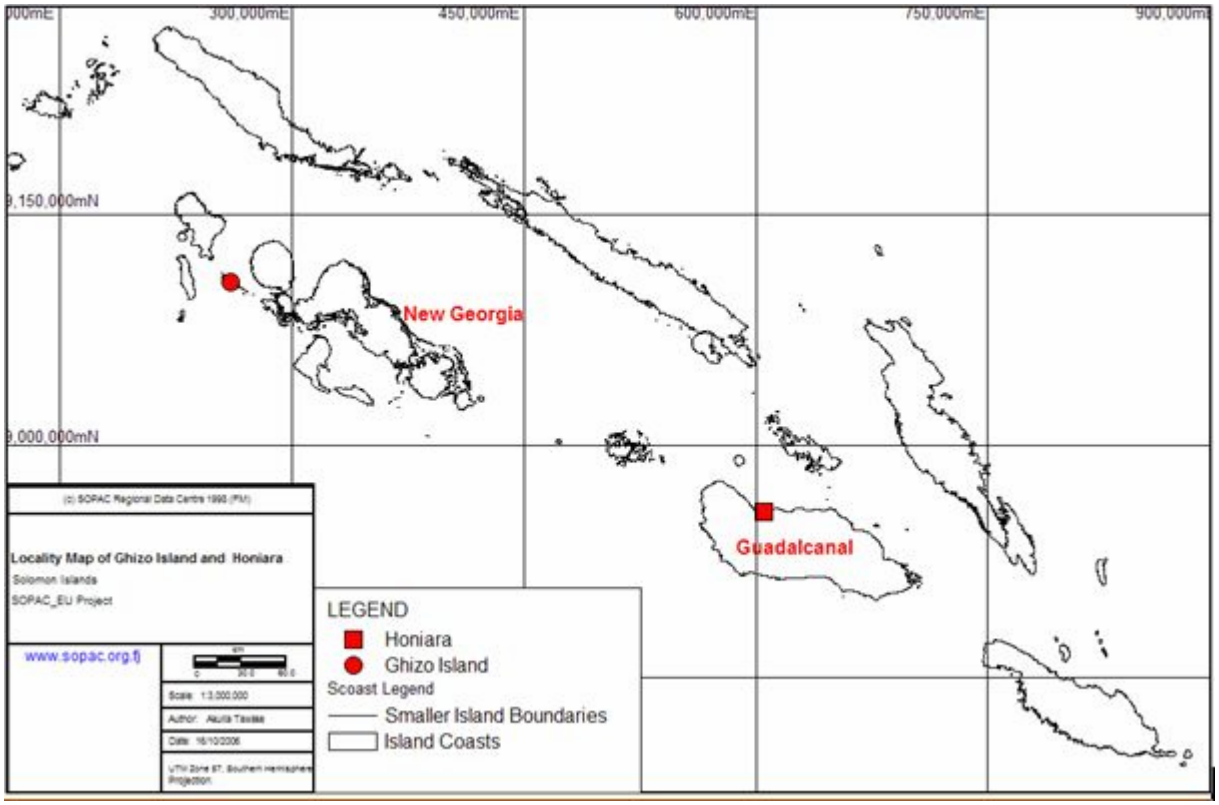


Figure 1. *Ghizo Island locality map.*

During a stakeholder consultation early in 2004, the Secretary of the Western Provincial Government requested the assessment of potential terrestrial aggregate sources on Ghizo Island as alternative sources of sand and gravel. In response a Project team, led by the then Director of Geology, made a reconnaissance visit to Ghizo in June 2004. The actual assessment was undertaken in July 2005 by the SOPAC-EU EDF8 Project in collaboration with the Department of Mines.

The assessment entailed identifying potential sites from geological maps to ascertain the extent of the rock outcrops, and sample collection for geotechnical analyses. All samples collected were sent to Fiji for appropriate tests.

1.1 Geology of Ghizo

A geology map of Ghizo Island is shown in Figure 2 (from Abraham et al., 1987) and explanatory notes are extracted from Dunkley (1986).

Ghizo is largely made up of two geological formations: sediments of the older Konggu Formation, are overlain by volcanics of the Ghizo Volcanic Formation. The Konggu Formation comprises the Mari Limestone Member overlain by the Kaindo Arenite Member. These two units occur in a north-westerly fashion in the central part of the island and crop out in other areas such as Mari Point.

The Ghizo Volcanic Formation is composed predominantly of breccias and breccio-conglomerates. The older basaltic breccia crops out to the west of the island and is overlain by polymict breccia and breccio-conglomerates that occur over a large area of the island. Clasts within the polymict breccia include basalt, andesite and well-rounded pebbles, cobbles and boulders of diorite, tonalite and granite. Andesitic breccias rest upon the polymict breccias in north to central Ghizo.

1.1.1 Konggu Formation

The Calcareous Limestone Mari Point Quarry (Figure 3) is part of the Mari Point Limestone Kaindo Arenite, a member of the Konggu Formation (Dunkley, 1986). It consists of both massive and interbedded sand and siltstone. This unit, as observed in the quarry and on the road, is powdery, vesicular and weak to moderately strong. It has been extensively applied as road gravel around Ghizo. This rock disintegrates relatively easily when subjected to constant loading and continuous heavy rain. As a result, the roads become muddy and boggy, proving the poor quality of materials being used.

1.1.2 Ghizo Volcanic Formation

The three volcanic breccia units that occur on Ghizo Island belong to the Ghizo Volcanic Formation.

1.1.2.1 Olivine Basalt Breccia

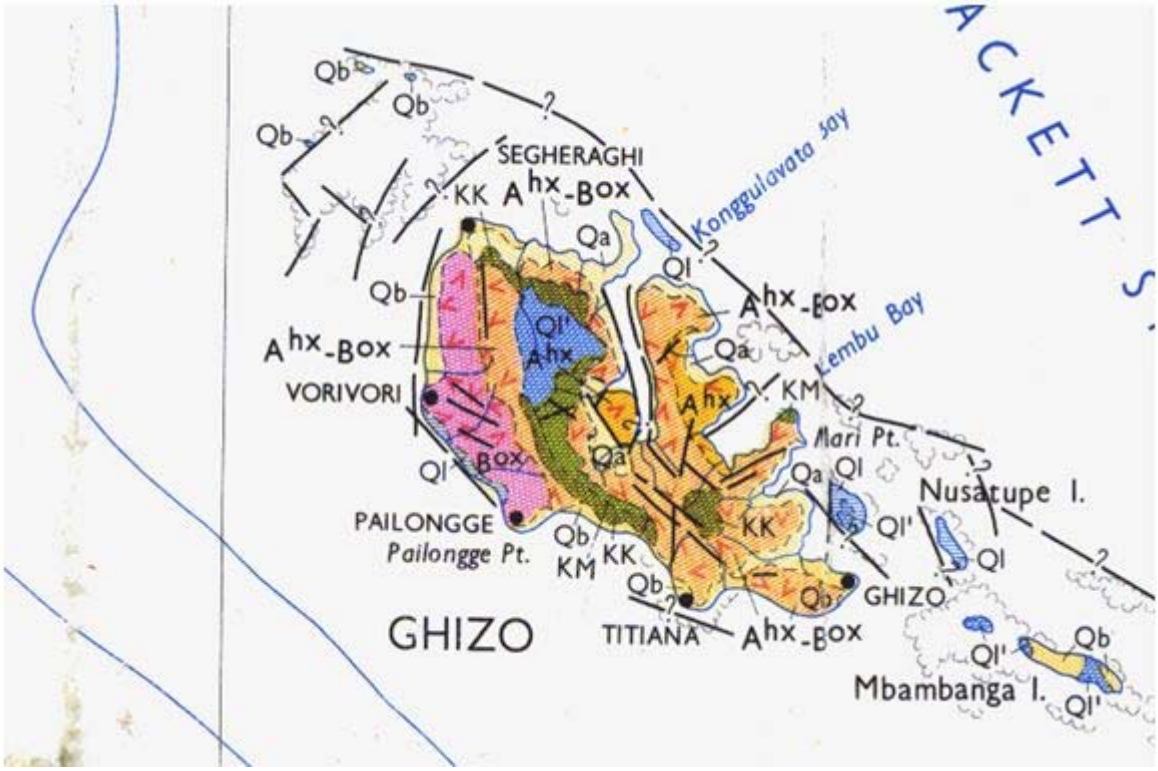
Discontinuous outcrops of the basaltic breccia unit occur along the main road between Saeragi and Pailoge Villages (Figure 4). This unit is the preferred source of aggregate because of its resistance to weathering: by visual estimation, it has a 70 : 30 % clast to matrix ratio. The basalt fragments within the breccia are variable in size; they are more resistant to weathering than the crumbly, highly weathered matrix. Coarse olivine crystals are visible and featured prominently in the groundmass.

Crushed materials of this unit were applied in some sections of the road in the western part of the island in 2004. During the 2005 visit, these road segments remained in excellent condition after more than a year compared to the deteriorated part of the road where the calcareous sediments had been used.

1.1.2.2 Polymict Breccia

The polymict breccia (Figure 5) unit occurs extensively on the south and eastern part of the island. This unit is made up of relatively smaller igneous rock fragments with a highly weathered sandy-clay matrix. Generally, this unit shows an extensive and intense weathering pattern particularly in the south-eastern part of the island; the clasts tend to show light to dark grey weathering whilst the matrix exhibited light to dark brown weathering.

Fresh, sub-rounded rock fragments of basalt, andesite, diorite and tonalite were observed in the breccias around Titiana Village and to the west of Gizo Town, with an approximate 50 : 50 clast to matrix ratio.



LEGEND

Qa	Alluvium
Qb	Beach deposits, mainly coralline
Ql	Limestone low uplifted reef
Ql'	Limestone; raised reef
KK	Siltstone and sandstones, calcareous in part
KM	Calcisiltites and calcarenites
Ahx	Hornblende andesite breccia
Ahx-Box	Polymictic breccia with clasts of hornblende andesite and olivine basalt
Box	Olivine basalt breccia, with lava in parts
—?— —?—	Fault, inferred

Figure 2*. Geology of Ghizo Island (from Abraham et al., 1987).*

1.1.2.3 Andesite Breccia
Only boulders of fresh andesite flow (presumed to be part of the andesite breccia unit) were found in one of the creeks that run into Lembu Bay (Figure 2). Samples collected from this location were very strong and compact when visually inspected and tested with a geological hammer. The samples contain fine- to medium-grained pyroxene. No fresh outcrop was found.

2. BACKGROUND

Information on the aggregates' development and management, and supply and demand in Ghizo were gathered through site visits. Personal interviews were also conducted with construction workers and aggregate users.

2.1 Sand and Gravel Supply

Most of the sand and gravel that have been used for construction, particularly in Gizo Town, are imported from the nearby bigger volcanic islands of Kolobagara, Rendova and Ranogga, as well as from Honiara. This is generally done on an individual-need basis for personal use. There is no retail supplier of sand and gravel in Ghizo. Construction companies find it cheaper to import their own supply rather than rely on a retail supplier selling at higher prices.

Most recent construction activities on the island are around the Gizo Town area. This includes residential and commercial buildings, a new wharf (funded by the EU), and road rehabilitation (funded by the Government of Japan). Construction activities outside Gizo Town were minimal during the 2004 and 2005 visits, except for road and seawall constructions using sand and gravel.

In a typical Ghizo village, concrete houses make up only 10% of the total (2 out of 20 houses), the remaining 90% being made from thatched leaves and timber. Hence the demand for sand and gravel in rural areas is insignificant.

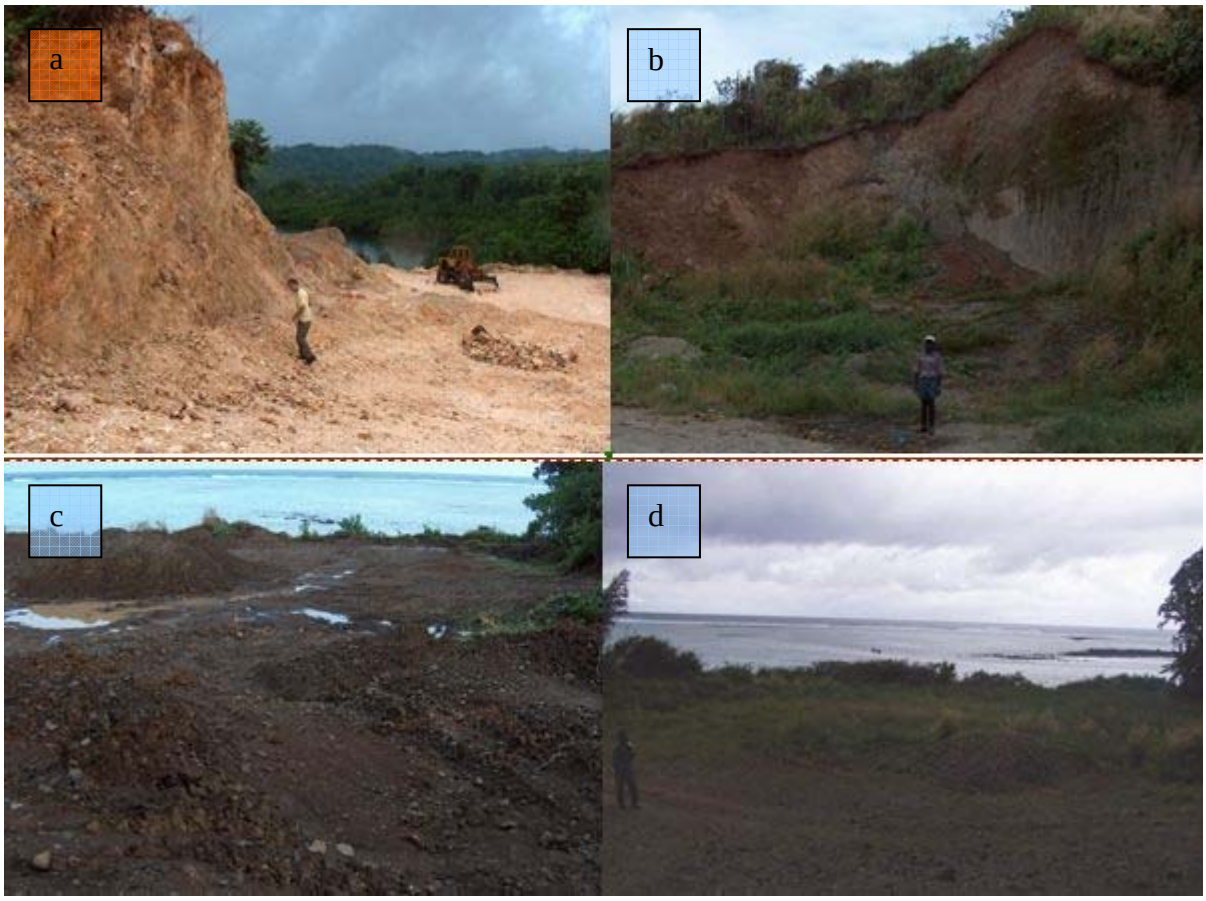


Figure 3. *Recent status of Ghizo quarries. a) Mari Point Quarry; b) Malakarava Quarry; c) Pailoge Quarry in June 2004; d) the abandoned Pailoge Quarry in July 2005.*

2.2 Aggregates Extraction in Ghizo

During the 2004 site visit, three small but recently active quarries were inspected; they had been developed during the Japanese Government-funded road upgrading project on the island in early 2004. This project had been carried out in preparation for the Melanesian Spearhead Group (MSG) meeting held in Gizo in May 2004.

The Calcareous Limestone Mari Point Quarry is located to the north-northeast of Gizo Town (Figure 3a). Located to the south of the town is the Malakarava Quarry (Figure 3b) where the moderately to highly weathered Polymict Breccia Unit was extracted. The Basalt Breccia Unit that contained basaltic lava and breccia was quarried at Pailoge Quarry (Figure 3c), located adjacent to Pailoge Village.

All three quarries have been abandoned since the completion of the 2004 road upgrading project. During the 2005 field assessment, there was no sign of recent activity in any of the quarries (Figure 3d). This illustrated that any initiative to develop aggregate sources on the island hinges on major infrastructure developments. Beach mining is generally insignificant around the island; scars of excavation were observed in some places where concrete houses and seawall are being constructed.

A note on the feasibility of a quarry operation to further assist any potential developer is given in Appendix 1. An interview with the UNDP Technical Adviser concerning the road upgrading Project in Ghizo in 2004 is summarised in Appendix 2.

2.3 Specification

The variation of aggregate impact and crushing values within specific rock type categories, or between broader rock groups, can be attributed to the influence of aggregate particle shape and geological features such as: bulk composition (silicate and carbonate rocks etc.), grain size, texture, structure and alteration (Smith and Collis, 1993). Generally the aggregates must be hard, durable and clean in order to be suitable for most applications.

The test results from the Ghizo samples must be compares with the specifications in Table 1 as minimum requirements and for the performance of each aggregate source. For the safety and durability of structures, more stringent criteria are required and specifications for high-quality concrete must be applied.

Table 1. *General specifications for rock tests.*

Parameter	**Minimum Acceptable Requirement**	**Reference**
Dry density	Not less than 2.5 g/cm^3	Smith and Collis (1993)
Water absorption	Not greater than 3% by weight	
Aggregate Crushing Value	Not more than 30%	
Los Angeles Abrasion Value	Not greater than 30%	
Compressive Strength	Not less than 20 MPa (depends on the impact angle)	Instruction Manual on Concrete Test Hammer
Point Load Strength	Not less than 3 MPa	Operating Instructions Point Load Test Apparatus 77-0110

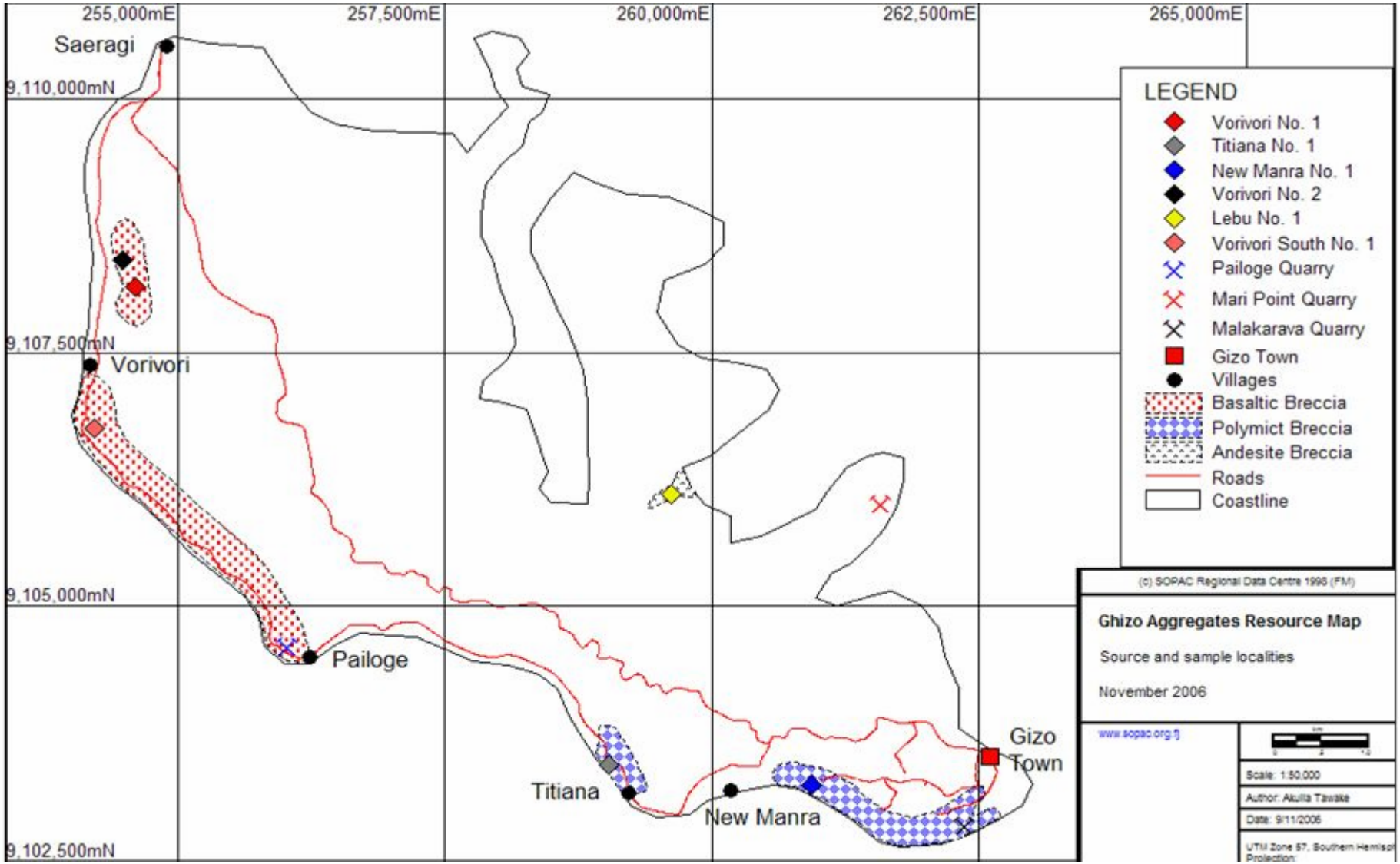


Figure 4. *Aggregates resource map of Ghizo Island showing potential source and sample localities.*

3. METHOD

The aggregates field survey was aided by the geological map of Ghizo and local field assistants. Various sites around the island were inspected in search of bigger and good-quality rock outcrops with potential to be developed as sources of sand and gravel. Volcanic rock exposures along the southern and western parts of Ghizo Island are considered potential sources of good-quality aggregates, hence the reconnaissance survey focused on the Olivine Basalt Breccia and Polymict Breccia Units there (Figure 5). While trying to locate any source of Andesite Breccia on the eastern part of the island, no significant fresh outcrop was discovered.

Significant breccia and lava flow outcrops of the Basalt Breccia Unit were located north of Vorivori Village. Samples collected at site Vorivori #1 comprised one bag of basalt lava flow and one of loose basalt fragments derived from the breccia. Similar loose basalt boulders were sampled at Vorivori #2 and Vorivori South #1.

The extensively occurring Polymict Breccia between Pailoge Village and Gizo Town was sampled at two sites along the southern coast of the island. Rock fragments contained in this breccia unit were selectively sampled west of Titiana Village (Titiana #1) and east of New Manra Village (New Manra #1). An additional sample of andesite boulder of Andesite Breccia was taken from Lebu creek (Lebu #1). All sample locations are shown in Figure 4.



Figure 5. *Examples of the two breccia unit outcrops in Ghizo: a) Olivine Basalt Breccia; b) Polymict Breccia.*

Selective sampling was necessary because matrices of the Basalt Breccia and Polymict Breccia units were generally weathered, weak and crumbly in most places (Figure 5) and unsuitable for the required analyses. All samples were subjected to basic geotechnical tests to ascertain the quality of the rocks and to determine the applications they are most suitable for.

Physical and mechanical tests that were carried out at SOPAC, Fiji are: Specific Gravity, Porosity, Petrographic examination, Schmidt Hammer, and the Point Load Tester (PLT).

Additional Los Angeles (LA) Abrasion Test and Aggregates Crushing Value (ACV) tests were conducted at the Public Works Department (PWD) Laboratory in Samabula, Fiji. All sample preparation and testing was in accordance with appropriate specifications, i.e. the Australian Standards (AS) and the American Society of Testing and Materials (ASTM).

The LA Abrasion test complied with the AS 1141.23–1980, which sets out procedures for the determination of the loss on abrasion of aggregate particles. The ACV test conformed to

AS 1141.21–1974. Insufficient samples had been collected from some sites: hence the ACV test for Titiana #1 and the LA Abrasion test for New Manra #1 were not done. For the same reason the PLT, LA Abrasion and ACV tests were not conducted on samples Vorivori South #1 and Lebu #1.

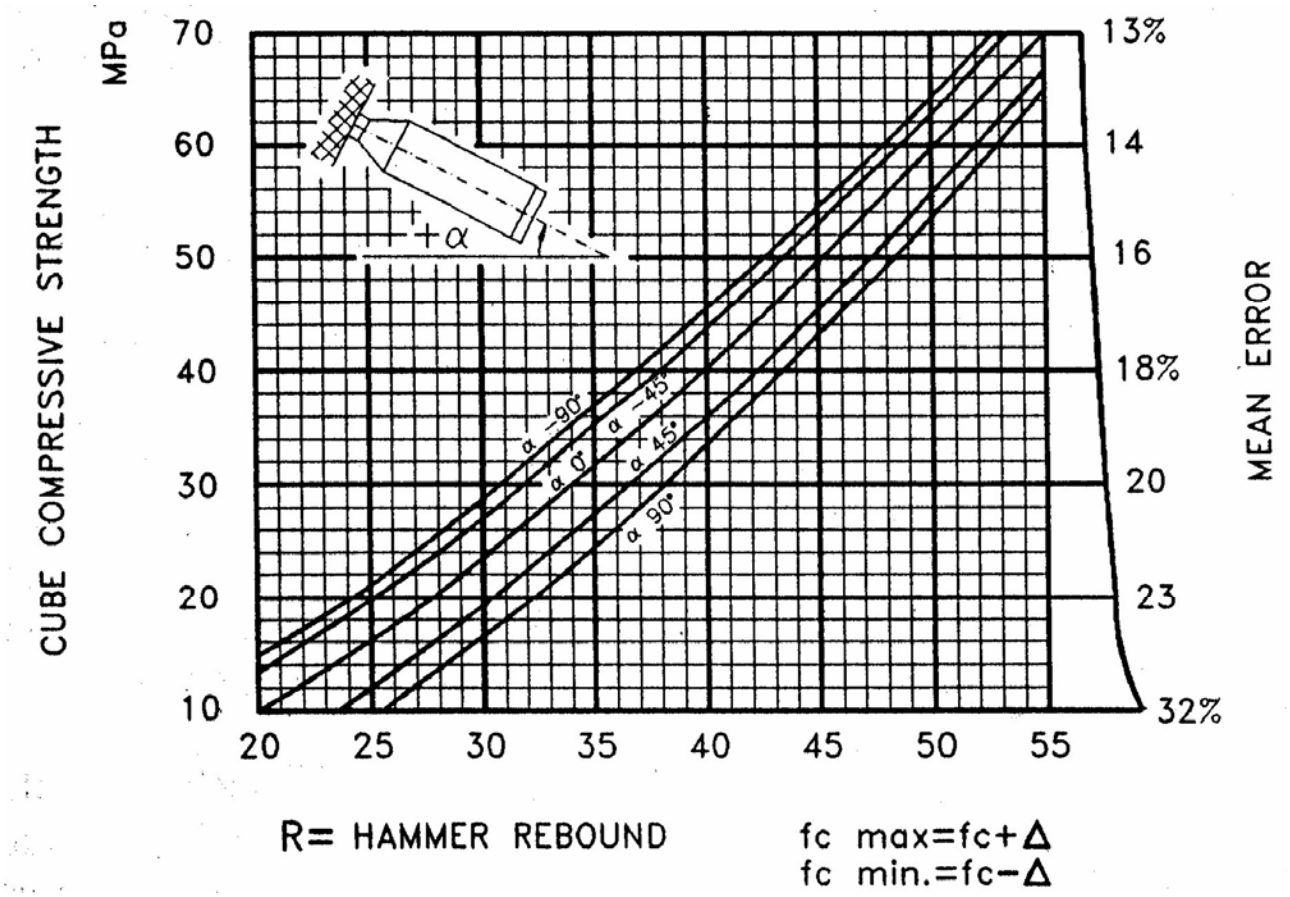


Figure 6. *Cube Compressive Strength Diagram, used to determine the resistance to compression on a cube sample (from User Guide, 2001).*

The Schmidt Hammer Test is a non-destructive test conforming to ASTM C 805, measuring the compressive strength of rock cubes and cylinders. Figure 6 can be used to calculate the strength of rock samples from the rebound readings obtained. The Point Load Test complied with the International Society of Rock Mechanics (ISRM) guidelines (Rusnak and Mark, 1999) in gauging the point load strength of each sample being tested.

4. RESULTS

The results of the tests are summarised below; they may not be representative of the entire rock source due to selective sampling (refer Discussion). Detailed petrographic descriptions of the samples are provided in Appendix 3.

4.1 Outcrop Description

The rocks of the Olivine Basalt Breccia Unit between Saeragi and Pailoge Villages are generally scattered boulders with only limited fresh outcrops. The only relatively large outcrop was found north of Vorivori where breccias and lava flows occur. This breccia unit is referred to as a clast-supported breccia with larger boulder-size rock fragments embedded.

By contrast, Polymict Breccia outcrops occur in frequent patches, some of which highly weathered, between Pailoge Village and Gizo Town. The biggest fresh outcrop occurs along the coast to the east of New Manra Village. This breccia unit contains relatively small clasts with approximately equal amounts of rock fragments and matrices. The clasts are supported by the weathered, sandy matrix hence it is referred to as a matrix-supported breccia.

The only fresh Andesite Breccia Unit occurs as andesite boulders in small streams to the east of the island. These breccia and flow boulders are strong, relatively compact, and may have derived from the clasts of the outcrops upstream.

Table 2 provides a summary of the physical appearance of each rock hand specimen.

Table 2. *Description of rock hand specimens collected from Ghizo Island.*

Sample No.	**Description of rocks at source**
Vorivori #1	Fine-grained olivine basalt lava flow, fresh and vesicular. Lava flow in basalt breccia. Basalt fragments in breccia are fresh, strong and vesicular.
Vorivori #2	Porphyritic basalt with weak, pervasive propylitic alteration (chlorite, epidote, pyrite). Olivine crystals (less than 1, to 2 mm) are present in minor amounts. Vesicles are commonly filled with carbonate and zeolite with iron-stained fractures.
Vorivori South #1	A basaltic lava boulder. Fresh and vesicular with weak pervasive propylitic alteration. Contains carbonate microveins.
Titiana #1	Predominantly porphyritic basalt and andesite fragments with minor plutonic and sedimentary clasts. Generally fresh and basalt fragments possess tiny vesicles. Rock fragments occur in moderately to highly weathered matrix and are generally sub-rounded to rounded ranging from less than 1 to 80 mm in length.
New Manra #1	Very fine-grained basaltic andesite boulder, compact, fresh and very strong. Rock fragments in moderately to highly weathered matrix are generally sub-rounded to rounded ranging from 1 to 120 mm in length. This is a rock clast in a matrix-supported conglomeratic breccia.
Lebu #1	Andesite fragment, fresh, compact and very strong. Fine-grained lava flow. Occurs as andesite boulder in Lebu creek.

4.2 Physical Tests

4.2.1 Water Content and Density

Table 3 lists the water contents and densities of the rock samples.

Table 3. *Water contents and densities of the Ghizo rock samples.*

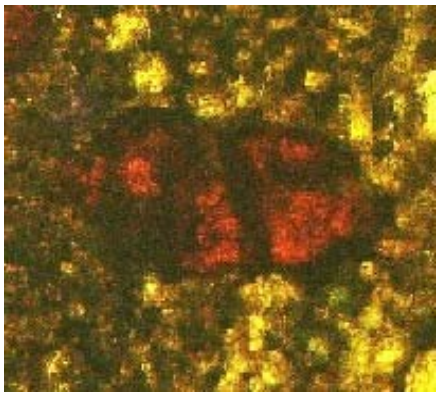
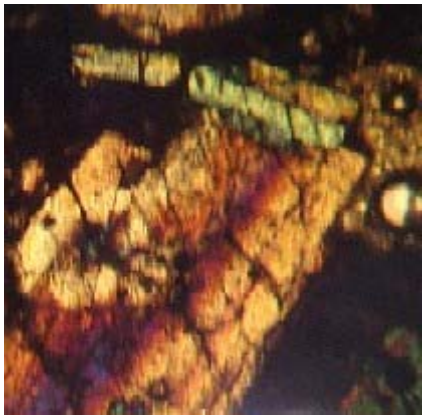
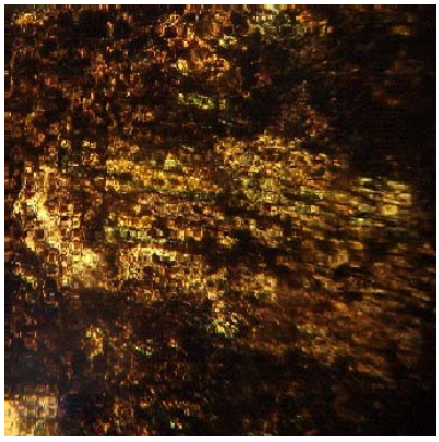
Sample ID	**% Water Content by Weight**	**Density (g/cm^3)**	
		Dry	**Wet**
Vorivori #1	0.32	2.79	2.80
Vorivori #2	1.21	2.63	2.66
Vorivori South #1	0.56	2.81	2.82
Titiana #1	1.88	2.49	2.54
New Manra #1	0.07	3.11	3.12
Lebu #1	0.11	2.85	2.85

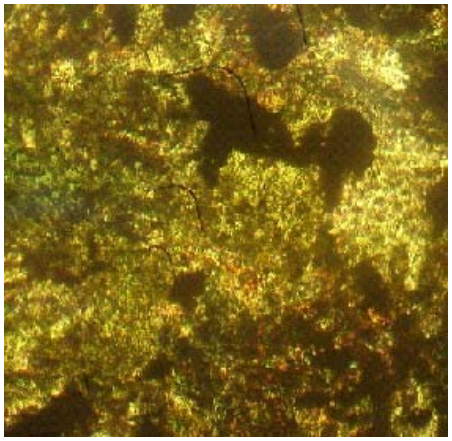
4.2.2 Petrography

Table 4 provides a summary description of the five thin sections prepared and examined. Full petrographic descriptions of these sections are given in Appendix 3.

Table 4. *Brief petrographic description of samples examined, with photomicrographs.*

Rock ID	Description	Photomicrograph
Vorivori #1	Generally euhedral plagioclase and olivine crystals occur as laths and phenocrysts respectively in a very fine, dark-green groundmass. Plagioclase is the dominant mineral (about 60%) and crystals normally do not exceed 3 mm in length. Olivine, with an approximate abundance of 20%, can be classified as the minor constituent with about 15% of opaque minerals. Other accessory minerals are present in smaller amounts. The photomicrograph on the right shows a euhedral olivine crystal under plane-polarized light. The width of field is about 3000 µm (3 mm)	

Vorivori #2	Plagioclase is the dominant mineral largely as laths in the groundmass. Simple twinning is observed in subhedral crystals. Olivine and augite occur in much smaller amounts with a combined abundance of 15%. Generally they are present as subhedral phenocryst in the groundmass. Opaque minerals are less abundant and occur as subhedral to anhedral crystals. The photomicrograph on the right shows a subhedral olivine crystal surrounded by anhedral plagioclase under plane-polarized light. The width of field is about 350 µm.	
Titiana #1	Fresh abundant plagioclase (70%) in variable sizes between 1000 and 1800 µm in length. Generally euhedral to subhedral crystals commonly exhibiting simple and multiple twinning with parallel striations. Phenocrysts of olivine and augite occur in minor amounts in the groundmass. Fine opaque minerals are disseminated in the groundmass and also occur as inclusions. The photomicrograph on the right shows multiple twinning in euhedral plagioclase crystals under cross-polarized light. The width of field is about 1400 µm.	
New Manra #1	Fine subhedral to anhedral plagioclase crystals are scattered in the groundmass. Cloudy edges of some plagioclase crystals are indicative of plagioclase being altered to sericite. Fine subhedral augite grains are rare. Opaque minerals occur in the groundmass in subhedral to anhedral forms and occasionally as inclusions in plagioclase. The photomicrograph on the right shows a subhedral form of plagioclase with cloudy edges under cross-polarized light. The width of field is about 850 µm.	

Lebu #1	Fine subhedral to anhedral plagioclase is observed in the groundmass in interlocking fashion. No mafic mineral was observed whereas the fine opaque minerals mostly in anhedral form are disseminated in the groundmass. The photomicrograph on the right shows anhedral forms of plagioclase and opaque minerals under plane-polarized light. The width of field is about 750 µm.	

4.3 Mechanical Tests

4.3.1 Schmidt Hammer Test

The results of the Schmidt Hammer tests are shown in Table 5 and Figure 7. Readings are obtained from the uppermost curve (α = –90°) in Figure 6.

Table 5. *Average compressive strengths of the Ghizo rock samples.*

Sample	Compressive Strength (MPa)		
	Before Drying	**After Drying**	**After Soaking**
Vorivori #1	61.6	58.1	63.3
Vorivori #2	56.5	53.4	56.1
Vorivori South #1	51.0	49.7	48.5
Titiana #1	46.8	46.0	43.6
New Manra #1	70.0	66.2	66.7
Lebu #1	60.7	59.3	57.6

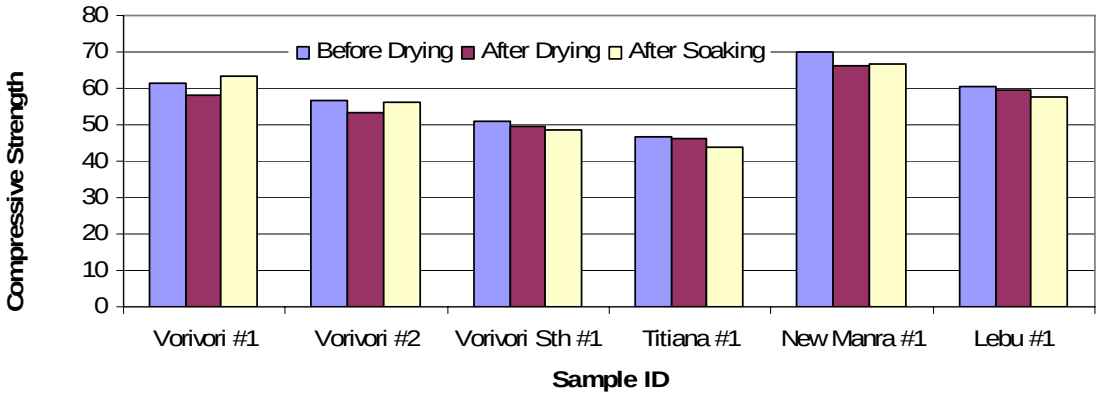


Figure 7. *Comparison of rock compressive strengths in megapascals (MPa) before drying, after drying and after soaking in water using the Schmidt Hammer.*

4.3.2 Point Load Test

The point load strengths and strength designation of the Ghizo rock samples using a Point Load Tester are shown in Table 6 and Figure 8. The point load strength of each sample is used to compute its strength designation using the nomogram shown in Appendix 4. Note that the unit for the point load strength (MN/m^2) is equivalent to MPa.

Table 6. *Point load strength of individual Ghizo rock cube samples.*

Sample ID	P (MN)	De2	Is (MN/m^2)	Strength Designation
Vorivori #1a	0.0270	0.00344	7.85	Very high
Vorivori #1b	0.0238	0.00303	7.86	Very high
Vorivori #1c	0.0292	0.00368	7.94	Very high
Vorivori #1d	0.0238	0.00325	7.31	Very high
Vorivori #2a	0.018	0.00402	4.47	Very high
Vorivori #2b	0.0179	0.00392	4.57	Very high
Titiana #1a	0.0198	0.00321	6.18	Very high
Titiana #1b	0.0184	0.00276	6.66	Very high
New Manra #1a	0.05	0.00243	20.61	Extremely high
New Manra #1b	0.0528	0.00245	21.53	Extremely high

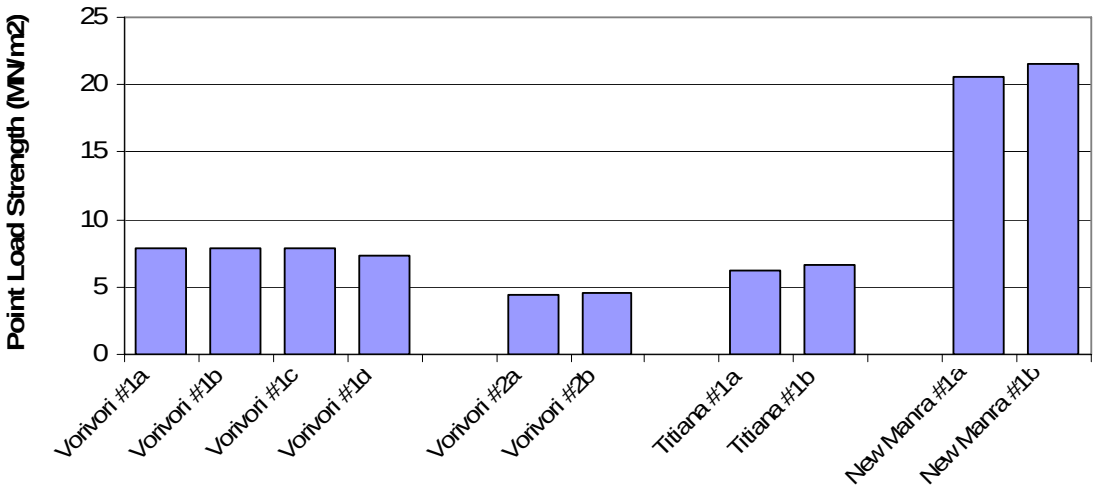


Figure 8. *Point load strength of individual samples in MN/m^2.(=MPa, magapascals).*

4.3.3 Los Angeles (LA) Abrasion and Aggregate Crushing Value (ACV) Tests

The LA Abrasion and ACV test details are given in Table7.

Table 7*. Results of the LA Abrasion and ACV tests of the Ghizo rock samples.*

Sample ID	Sample Type	LA Abrasion Value (%)	ACV (%)
Vorivori #1A	Clasts in breccia	16	23
Vorivori #1B	Lava flow	15	21.8
Titiana #1	Clasts in breccia	17	-
New Manra #1	Clasts in breccia	-	24

5. DISCUSSION

5.1 Vorivori Samples

The Vorivori samples include Vorivori #1, Vorivori #2 and Vorivori South #1. Test results show the water contents by weight of all three samples are insignificant. Their dry densities, 2.79, 2.63 and 2.81 g/cm^3, respectively, show that the clasts and lava flows of the Basalt Breccia are generally compact and strong. Vorivori #1 and Vorivori South #1, which are composed of basalt lava flow, show less porosity and are relatively heavy compared to Vorivori #2. The greater difference in the dry and wet densities of Vorivori #2 signifies a more porous rock sample.

Petrographic analysis reveals that the Vorivori samples are fresh and compact with fine to medium-grained phenocrysts in the groundmass. The absence of reactive silica and alteration clay minerals further support that Vorivori rock is a good-quality aggregate source.

The average compressive strengths of all three Vorivori samples are relatively high, indicating that the rocks are brittle and strong. The samples exhibit only slight changes in strength when subjected to heat and water, indicating that they remain stable under those conditions. Results of the point load tests (PLT) consistently record values above 7 MN/m^2 failure strength, indicating very high strength.

The LA Abrasion and the ACV test results display low abrasion and crushing values, respectively. However, the lava flow (Vorivori #1B) exhibits higher abrasion and crushing resistance in both tests compared to the clasts in breccia (Vorivori #1A). This is consistent with the general expectation that lava flows are considered good aggregates source has superior strength and durability. The LA Abrasion and ACV have therefore confirmed the results obtained from the Schmidt Hammer and PLT tests.

5.2 Titiana, New Manra and Lebu Samples

The Titiana and New Manra samples differed in water content, as well as dry and wet densities. This is indicative of the differing properties of various rock fragments in the Polymict Breccia Unit. Sample New Manra #1 records the least percentage water with the highest dry and wet densities, signifying highly compact and heavy rock fragments.

These results are supported by mechanical tests of rock samples. New Manra #1 continue to display excellent readings of compressive strength in both the Schmidt Hammer test and the PLT. The highest readings of a compressive strength (70 MPa) and point load strength (21.53 MPa) earn the New Manra sample an extremely high strength designation. All other samples record relatively low readings, yet their strength designations are all very high.

The LA Abrasion value of Titiana #1 is 17%, and the ACV of New Manra #1 24%. Both readings are slightly higher than for the Vorivori samples, indicating that they are slightly less resistant to wear, even though the values for all rock fragments are well below the minimum requirements.

The Lebu sample (Lebu #1) has high dry and wet densities with very low water content, indicating heavy and compact rock with very high compressive strength. Since no significant outcrop was discovered in the Lebu area, which also has an accessibility problem, this material is not being considered for resource assessment.

The petrographic analysis reveals variation in mineral abundance and composition of these three rock samples. The samples are fresh and compact with relatively lesser felsic and mafic phenocrysts in the groundmass. The presence of insignificant amount of clay as alteration product of plagioclase does not appear to affect the strength: the actual strength measured remains high for all samples. The interlocking fashion of plagioclase in the groundmass of sample Lebu #1 may contribute to its high strength.

It should be noted the rock fragments collected and used for these tests do not necessarily represent the physical and mechanical behaviour of all the different rock fragments that occur in the area. Nevertheless the different values and variations within a sample and among the different Ghizo samples have consistently exhibited properties of good aggregates sources.

6. CONCLUSION

The Basalt Breccia Unit may not be the best material in existence, but is certainly the best available source of aggregates on Ghizo Island. Both the Polymict Breccia and the Basalt Breccia Units exhibit good geotechnical behaviour. They can be used for road upgrading and sealing once screened and crushed. However the lower abundance of rock fragments in the Polymict Breccia (clast to matrix ratio 50 : 50 %) has favoured the Basalt Breccia (70 : 30 %). Because they are relatively weathered and crumbly, the matrices in the breccia are considered waste whereas the clasts and lava flows are classified as suitable aggregate sources.

The limited fresh exposures of these two volcanic units in the western and southern parts of the island could be developed to meet demands of gravel for road and building construction in the short to medium term. Long-term solutions will require the importation of sand and gravel from neighbouring bigger volcanic islands to supplement the locally identified terrestrial sources.

7. RECOMMENDATIONS

- For quality sand and gravel, the rock fragments of the Polymict and the Basalt breccia units and associated lava flows should be developed to supply gravel in Ghizo.
- The poor quality of the calcareous sediment rocks that occur at Mari Point makes them suitable only as sub-grade and sub-base materials for road rehabilitation and upgrading.
- Necessary equipment, including a portable rock crusher, should be acquired for a small quarry operation on Ghizo Island.
- Government assistance is required for any potential developer to set up a quarry in Ghizo. This could be in the form of a joint venture with the Ministry of Works in Ghizo, through the provision of reasonable equipment and manpower.
- Continued import of sand and gravel from neighbouring islands is required to supplement the limited local terrestrial aggregates supply for construction purposes.
- Sand and gravel extracted from coastal areas of the neighbouring islands requires proper washing with fresh water before use.
- Any aggregate developer in Ghizo should incorporate appropriate measures into the management of the quarry operations in regard to relevant environmental and social issues. These are highlighted in Tawake's (2008) *Proposed Framework and Guidelines for Sustainable Aggregates Development and Management in the Solomon Islands*.

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APPENDIX 1: Feasibility of Aggregates Extraction Operations

A feasibility study is normally carried out once an aggregate resource is confirmed and before developing the resource. For a developer, such a study is vital in determining the economic viability of a medium to large extraction operation. The major issues that need to be considered in a feasibility study of any terrestrial aggregates extraction on Ghizo Island are:

- Quality and quantity of resource
- Land tenure
- Availability of market
- Accessibility of the resource
- Distance from source to market
- Environmental impacts
- Social Issues

Quality and Quantity of the Source

A preliminary study of aggregate sources may include geological, geophysical and geotechnical assessment. In the initial assessment stage, the determination of the quality and quantity of the source is essential in ascertaining the potential of the source being investigated. Geotechnical tests are usually required to further ascertain the behaviour and performance of the aggregates source.

The quantity of the source can be estimated by direct measurement, geological mapping and the interpretation of geophysical data in which the resource can be delineated laterally and vertically. Drilling is another way of determining the depth of the resource but can have high associated costs.

Land Tenure

Security of land tenure is essential in attracting potential quarry developers to Ghizo. Land ownership is a sensitive issue in the Solomon Islands hence this should be addressed in the early stage of stakeholder consultation. In additional, the right for land access and the acquisition of a lease must be sorted out prior to development. The national government together with the Western Provincial Administration should assist resource owners and the developer in reaching an amicable agreement.

Availability of Market

It is essential to gauge the demand for aggregates in Ghizo during the feasibility study. It can be deduced from the existing rate of construction in Gizo Town, the amount of consumption from the local villages, and the potential buyers from outside Ghizo (from nearby islands). In addition, it might be worthwhile to estimate the amount of aggregates required for upgrading and sealing the existing roads around the island. A weekly sales forecast will assist in determining the appropriate scale of operation.

Accessibility of the Resource

The viability of an extraction operation may hinge on how accessible the resource is. This is particularly so for larger volcanic islandswhere good aggregate materials occur in areas without access roads. Ghizo is a relatively small island and potential aggregate sources are close to the road that encircles the island.

Distance from Source to Market

A developer needs to consider the distance from the source to major markets. In Ghizo, the major demand for sand and gravel comes from Gizo Town so the operation costs of running a quarry must include the estimated cost of carting sand and gravel to the town centre as well as the cost of fuel consumption. The distance from source to market can influence the selling prices of aggregates.

Environmental Impacts

A quarry between Pailoge and Vorivori would produce a significant amount of clayey material from the highly weathered, crumbly matrix in the breccia units. The most obvious environmental effect is the possibility of muddy waters seeping into the sea. Large quantities of this material can cause prolonged sediment suspension in the water column which, in turn, affects marine life in the surrounding areas. This may upset the marine food sources for the local communities.

The present Pailoge Quarry near Pailoge Village needs improvement in the overall management of the quarrying activities and the environment, in the event of a future re-establishment. Other potential sites could be investigated for quarrying.

Social Impacts

One of the positive impacts of quarrying in Ghizo is that it will contribute to the economic well-being of certain individuals and sections of the community. People will get employment, landowners will receive royalty payments, and as a result will benefit other small businesses such as taxi proprietors and shop owners in villages.

On the other hand, developers may encounter issues pertaining to resource ownership and royalty payment with the local communities. These are common problems in most Pacific Island Countries that may impact on the quarry operation. Another issue that may arise is the protection of culturally significant sites. The developer should try and address these issues through continued dialogue with relevant agencies. The safety of individuals in nearby villages / settlements must also be taken care of during quarry operations.

APPENDIX 2: Interview with UNDP Technical Adviser

Interview with Mukesh Gupta, Chief Technical Adviser, Community Infrastructure Rehabilitation Project, UNDP, Honiara conducted by Reg Sanday, Thursday 24 June 2004

Questions by Akuila Tawake; Transcribed by Reg Sanday, 30 June 2004.

Background to the Project

The Ghizo Road is about 26 km; half inland and half coastal. The project was paid for from a US$1-million grant from the Government of Japan's Trust Fund for Human Security, which is managed by the United Nations. The one-year project ends at the middle of next month (July) and it targeted road improvements in three Provinces – Western Province, Malaita and Guadalcanal. Mr Gupta ends his contract in the Solomons in August 2004. He has been involved in numerous road upgrading projects around the world.

Prior to the rehabilitation project, both the inland and coastal roads were impassable. Two sources of aggregates for the Ghizo Road were: (a) a white kind of gravel from a quarry some 5 km from Gizo Town; (b) some 150–200 truckloads from an old quarry at Pailoge. The best materials belonged to landowners. Standard compensation rate payable to landowners by the truckload was $35.

The seawall on the western end of the island was built using UNDP resources. The main reason for construction was to prevent coastal erosion. More than 200 members of the community were involved in its construction, especially women. It was a major source of income for the rural community. Some gravel was taken from the sea and paid to the women on a contract basis.

The project restored 7–8 metres road width, which in many places had been reduced to 1–2 metres.

Rather than using Gambian baskets, the community preferred solutions so as to promote employment generation.

Five new culverts, three box culverts and three new fords were built plus all bridges upgraded with approach ramps so that vehicles could use them.

Questions and answers

Q: Why were calcareous sand and siltstones used for the road upgrading in Ghizo instead of the relatively good-quality volcanic materials that occur to the west of the island?

A: It was the only material available. The very limited supplies of black rock were used on a selective basis. Using more of the black rock could have endangered that part of the island.

Q: What volume of aggregates is needed to seal 100 metres of a standard two-lane road?

A: New construction: a 7-metre wide road 15 cm thick requires 100 cubic metres of gravel every 100 metres. For improvements on existing road: 20–25% of above.

Q: Are there plans for sealing the Ghizo Road?

A: No, but something may eventuate in response to the EU's US$35-million Transportation Trust Fund that has been established in the Solomons. About 90% of this money is likely to be spent on the road sector. How and where this money is spent will most likely be determined by a recently commissioned study by the Asian Development Bank on an Integrated Transportation and Infrastructure Study, to be completed towards the end of 2004.

Q: What were some of the problems encountered in the rehabilitation of the Ghizo road?

A: In no specific order of importance, some of the major problems include:

- High rainfall: approx 7,000 mm per annum. It rains almost every day for 9 months of the year. High rainfall causes problems with drainage, work disruptions, etc. There were serious drainage problems encountered on the coastal portion of the road. Private landowners did not allow construction of drains unless they were paid compensation.
- Landowners seeking rent – although most land on Ghizo is supposedly freehold land there were many demands for compensation from alleged landowners.
- Limited sources of aggregates.

Q: In your opinion, what the market is like for aggregates, if a quarry was to be established on Ghizo?

A: There will be a need for chipped rock if the Munda International Airport is built, if the Ghizo airstrip is sealed and if the Munda Noro Road (16 km) goes ahead as is being talked about.

APPENDIX 3: Petrographic analyses of Ghizo rock samples

PETROGRAPHIC DESCRIPTION – Vorivori #1

PROJECT. SOPAC-EU SI05

THIN SECTION NO. 1 **COUNTRY.** Solomon Islands

SAMPLE ID. Vorivori #1 **LOCALITY.** Western Ghizo Island

ROCK NAME. Olivine Basalt Breccia **LATITUDE.** S 08° 03' 44.2"

OCCURRENCE. Lava flow in Breccia **LONGITUDE.** E 156° 46' 24.2"

FIELD RELATIONS. Belongs to the Ghizo Volcanic Formation

HAND SPECIMEN. Fine grained olivine basalt lava flow, fresh and vesicular.

GENERAL DESCRIPTION. Fresh, medium grained porphyritic basalt lava flow with infrequent vesicles. Coarse olivine crystals are visible in places.

DETAILED DESCRIPTION. Plagioclase: Generally 400 x 2000 µm in dimension but not more than 3000 µm in length. Occurs mainly as elongate euhedral crystals. Simple twinning observed in places with parallel striations. Cloudy edges are visible in some grains indicating the presence of white clay.

Olivine: Between 1000 and 2500 µm in diameter and occurs as phenocrysts in the groundmass. Some crystals are zoned as exhibited in the photomicrograph in Table 4. Euhedral crystals are common with conchoidal fractures.

Opaques: Not more than 500 µm in diameter. Generally occur as subhedral toanhedral crystals in the groundmass and rare inclusions in olivine.

COLOUR INDEX

	Oliv	Pyrox	**Horn**	**Plag**	**Biot**	**Opaq**	**Chlor**	**Epidote**	**Calc**	**Total**
%	20			60		15	3	2		100
Size (mm)										
Alteration	chlorite			sericite						

TEXTURE. porphyritic

GROUNDMASS. medium grained

ACCESSORIES. chlorite and epidote

ALTERATION. weak propylitic and weakly sericitised plagioclase

PHOTOMICROGRAPH. Refer to Table 4 **AGE.** Upper Miocene

PETROLOGIST. A. Tawake **DATE.** 12/03/07

PETROGRAPHIC DESCRIPTION – Vorivori #2

PROJECT. SOPAC-EU SI05

THIN SECTION NO. 2 **COUNTRY.** Solomon Islands

SAMPLE ID. Vorivori #2 **LOCALITY.** Western Ghizo Island

ROCK NAME. Olivine Basalt Breccia **LATITUDE.** S 08° 03' 35.8"

OCCURRENCE. Basalt clasts in clast-supported breccia **LONGITUDE.** E 156° 46' 20.3"

FIELD RELATIONS. Belongs to the Ghizo Volcanic Formation

HAND SPECIMEN. Fine to medium grained basalt in breccia, fresh and partly vesicular.

GENERAL DESCRIPTION. Porphyritic olivine basalt with weak pervasive propylitic alteration. Fine subhedral to anhedral crystals of plagioclase are common with minor olivine and opaques.

DETAILED DESCRIPTION. Plagioclase: Occurs mainly as laths in the groundmass and occasionally as phenocrysts not more than 50 µm in length. Crystal forms are subhedral to anhedral and also observed in pods of grain in the groundmass.

Olivine: Occasional with crystal diameter not exceeding 50 µm. Generally occur as subhedral phenocrysts in groundmass.

Opaques: Not exceeding 30 µm in diameter. Generally exhibits subhedral to anhedral crystals.

COLOUR INDEX

	Oliv	Pyrox	**Horn**	**Plag**	**Biot**	**Opaq**	**Chlor**	**Epidote**	**Calc**	**Total**
%	15			70		10	3	2		100
Size (µm)										
Alteration										

TEXTURE. porphyritic

GROUNDMASS. fine grained

ACCESSORIES. chlorite and epidote

ALTERATION. weak propylitic

PHOTOMICROGRAPH. Refer to Table 4 **AGE.** Upper Miocene

PETROLOGIST. A. Tawake **DATE.** 12/03/07

PETROGRAPHIC DESCRIPTION – Titiana #1

PROJECT. SOPAC-EU SI05

THIN SECTION NO. 3 **COUNTRY.** Solomon Islands

SAMPLE ID. Titiana #1 **LOCALITY.** Southern Ghizo Island

ROCK NAME. Polymict Breccia **LATITUDE.** S 08° 06' 18.0"

OCCURRENCE. Basalt and andesite fragments in conglomeratic polymict breccia **LONGITUDE.** E 156° 48' 47.8"

FIELD RELATIONS. Belongs to the Ghizo Volcanic Formation

HAND SPECIMEN. Generally fresh rounded basalt fragments with tiny vesicles.

GENERAL DESCRIPTION. Generally fresh with abundant plagioclase in variable sizes with minor olivine and augite in the groundmass. Opaque minerals are present in lesser amount.

DETAILED DESCRIPTION. Plagioclase: range between 800 – 1800 µm in length. Occurs in laths and pods of grain where euhedral and subhedral crystals frequently exhibit simple and multiple twinning with parallel striations.

Olivine: 1000 µm in diameter. Generally occurs in lesser amount as subhedral phenocrysts in groundmass where conchoidal fractures are observed in some crystals.

Augite: Rare but occurs as subhedral to anhedral crystals in the groundmass. Grains are commonly 400 – 600 µm in diameter.

Opaques: Occur as inclusions in olivine as well as disseminated fine forms in the groundmass. Generally present as subhedral to anhedral crystal not exceeding 300 µm in diameter.

COLOUR INDEX

	Oliv	C/pyrox	Horn	Plag	Biot	Opaq	Chlor	Epidote	Calc	Total
%	10	5		70		10	3	3	4	100
Size (mm)										
Alteration										

TEXTURE. porphyritic

GROUNDMASS. fine to medium grained

ACCESSORIES. chlorite, calcite and epidote

ALTERATION. weak propylitic

PHOTOMICROGRAPH. Refer to Table 4 **AGE.** Upper Miocene

PETROLOGIST. A. Tawake **DATE.** 12/03/07

PETROGRAPHIC DESCRIPTION – New Manra #1

PROJECT. SOPAC-EU SI05

THIN SECTION NO. 4 **COUNTRY.** Solomon Islands

SAMPLE ID. New Manra #1 **LOCALITY.** Southern Ghizo Island

ROCK NAME. Polymict Breccia **LATITUDE.** S 08° 06' 38.2"

OCCURRENCE. Igneous rock fragments in conglomeratic polymict breccia **LONGITUDE.** E 156° 50' 04.9"

FIELD RELATIONS. Belongs to the Ghizo Volcanic Formation

HAND SPECIMEN. Fresh, fine grained basalt fragments, compact and very strong.

GENERAL DESCRIPTION. Fine plagioclase crystal are scattered in the dark green to black groundmass. Occasional fine grained augite and opaque minerals are observed.

DETAILED DESCRIPTION. Plagioclase: Fine subhedral to anhedral crystals not exceeding 1000 µm in length. Simple twinning with parallel striations is observed with numerous clusters of grains being scattered in the groundmass. Weak cloudy crystal edges are observed and are indicative of plagioclase being slightly altered to sericite.

Augite: Rare, fine grained and occurs as subhedral crystals not more than 300 µm in diameter.

Opaque: Generally occur in fine grains not more than 100 µm in diameter. Commonly present as disseminated subhedral to anhedral crystals in the groundmass.

COLOUR INDEX

	Oliv	C/Pyrox	Horn	Plag	Biot	Opaq	Chlor	Apat	Calc	Total
%		5		85		5	3	2		100
Size (mm)										
Alteration				sericite						

TEXTURE. equigranular

GROUNDMASS. fine grained

ACCESSORIES. chlorite and apatite

ALTERATION. weakly sericitised plagioclase

PHOTOMICROGRAPH. Refer to Table 4 **AGE.** Upper Miocene

PETROLOGIST. A. Tawake **DATE.** 12/03/07

PETROGRAPHIC DESCRIPTION – Lebu #1

PROJECT. SOPAC-EU SI05

THIN SECTION NO. 5 **COUNTRY.** Solomon Islands

SAMPLE ID. Lebu #1 **LOCALITY.** North-eastern Ghizo Island

ROCK NAME. Andesite Breccia **LATITUDE.** S 08° 04' 50.9"

OCCURRENCE. Andesite boulder in creek **LONGITUDE.** E 156° 49' 07.3"

FIELD RELATIONS. Belongs to the Ghizo Volcanic Formation

HAND SPECIMEN. Fresh, compact and fine grained andesite fragment.

GENERAL DESCRIPTION. Fresh, fine grained and dark grey to black in colour. Subhedral to anhedral crystals of plagioclase in interlocking fashion occur in the fine groundmass. Fine anhedral opaques are disseminated in the groundmass.

DETAILED DESCRIPTION. Plagioclase: Mainly occurs as subhedral to anhedral crystals in interlocking fashion in the groundmass. Subhedral crystals do not exceed 400 µm in length and simple twinning is common.

Augite: None was found in this thin section.

Opaques: Occurs largely in fine anhedral form in variable sizes not exceeding 300 µm in length. Opaques are disseminated in the groundmass.

COLOUR INDEX

	Oliv	C/Pyrox	Horn	Plag	Biot	Opaq	Chlor	Apat	Calc	Total
%				80		15	3	2		100
Size (mm)										
Alteration										

TEXTURE. equigranular

GROUNDMASS. fine grained and interlocking

ACCESSORIES. chlorite

ALTERATION. fresh

PHOTOMICROGRAPH. Refer to Table 4 **AGE.** Upper Miocene

PETROLOGIST A. Tawake **DATE.** 12/03/07

APPENDIX 4

Nomogram for computing point load strength designation (from ELE International, 2003).

