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YASAWA ISLANDS FIELD TRIP NOTES
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Geology of Yasawa Islands

by

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Photo of west coast of Waya island (Paul Taylor, 2016)

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[*The island motif used here is a reproduction of a portion of a Fijian Festive Masi. Image downloaded from the "Tapa Cloths from the Pacific and Artwork" website: www.tapapacifica.com, accessed 13 May 2016. The use of the image is gratefully acknowledged*.]

NOTES FOR YASAWA EXCURSION

This has been adapted from the draft Bulletin on my mapping of the western islands. Details for Yalewa Kalou (on the Vanua Levu Platform) are omitted. There is much here that is not relevant to this one-day excursion, but might be of interest.

Table 1. Areas of island groups.

Qalito, Mociu, Wadigi	6 ha
Mamanuca Group (including Mana and Nukuimana)	564 ha
Mamanuca Rocks	of the order of 50 m^2
Narokorokoyawa Group	132.6 ha
Sand cays in Nadi Waters	about 36 ha
Vomo and Vomo Lailai	115 ha
White Rock	0.3 ha
Yasawa Group (including Kuata)	14 312 ha
Yalewa Kalou	27.4 ha
Viwa cluster (plus Nuku, Nukuvatu)	501 ha

Table 2. Populations of islands, south to north.

	1976	1986	1996
Tai (resort, opened late 1960s)	*nk*	*nk*	143
Luvuka (resort, opened about 1980?)	nil	*nk*	11
Kadavulailai (resort, built 2000)	nil	nil	nil
Navini (resort, opened about 1985)	nil	*nk*	26
Vunivadra (resort, opened late 1980s or early 1990s)	nil	*nk*	*nk*
Wadigi (resort)	nil	nil	2
Qalito (resort, opened July 1966)	nil?	*nk*	84
Mana (resort, opened 4 November 1972)	~100	448	485
Matamanoa (resort, opened late 1980s)	nil	nil	27
Tavua (one village)	101	136	174
Yanuya (one village)	288	404	315
Tokoriki (a household, and resort opened Jan. 1990)	1 fam.	1 fam.	60
Vomo (resort, opened early 1990s)	nil	nil	64
Kuata (resort opened in 1990s)	nil	nil	*nk*
Wayasewa (two villages plus resorts)	*nk*	202	*nk*
Waya (four villages, and resorts from 1990s)	700*	929	1044
Naviti (seven villages plus resorts)	1295	1376	1574
Yaqeta (one village, one resort in 21st Century)	270	368	*nk*
Matacawalevu (two villages and a mission)	296	387	756
Nanuyalevu (resort, opened 1979)	nil	*nk*	11
Nanuyasewa (one settlement plus resorts)	*nk*	39	36
Tavewa (isolated houses and small resorts)	*nk*	*nk*	96
Nacula (four villages plus resorts)	598	812	724
Yasawa (seven villages plus resorts)	762	941	880
Viwa (two villages, Yakani now deserted, plus resort)	303	237	258

nk = not known
1 fam. – 1 family
* this probably includes Wayasewa
Names in italics – not permanently inhabited until resorts were built.

These lists are for my study area, comprising the Malolo (part), Mamanuca, Narokorokoyawa and Yasawa Groups, plus the Viwa cluster and the islands in Nadi waters which are not in the Yasawa Group *sensu stricto*.

SUMMARY

Stratigraphy

Surficial deposits (Holocene and perhaps older) – reefal ("coral") sand, beach-rock, alluvium, sand dunes

Tokalau Limestone Group
Ucuna Limestone (emerged coral-algal reefs; Pleistocene)
Yaqeta Limestone (massive limestone; Yaqeta only; younger than the Nato Basalt)

Yasawa Volcanic Group (Late Miocene and perhaps also Early Pliocene)

(Yasawa and islands further south)
Yasawa Andesite (breccia, hornblende andesite, forms one island off Yasawa)
Naitataniika Sandstone largely basaltic but includes other compositions, as Nabukeru Breccia)
Nabukeru Breccia (largely basaltic but includes pyroxene andesite, hornblende andesite, minor dacite; includes subordinate sandstone)
Cosiga Pillow Lavas (includes autobreccia, reworked breccia, subordinate finer volcaniclastics)
Bukama Dacite (tuff, lapillistone)

(Central part of the chain)
Matacawalevu Andesite (flows or perhaps fine-grained tuff; hard, fresh)
Navotua Andesite (pyroxene andesite, intrusive and hydroclastic, wholly within the Drola Hydroclastites)
Nato Basalt (subaerial, flows, breccia, tuff, basalt)
Vatuya Limestone (within the Drola Hydroclastites and other formations)
Drola Hydroclastites (mostly basalt)

(Waya group and Vomo, Vomo Lailai)
Vomo Andesite (breccia and tuff, pyroxene andesite; within Nalauwaki Andesite)
Loto Basalt (breccia and tuff, olivine basalt with fresh olivine; within Nalauwaki Andesite)
Nalauwaki Andesite (hornblende and pyroxene andesites; mostly breccia and finer volcaniclastics)
Monu Dacite (mainly breccia – see below; also within Nalauwaki Andesite)

(Mamanuca Group)
Nautanivono Andesite (acid andesite with acicular hornblende, breccia and tuff, partly hydroclastic)
Monu Dacite (breccia and tuff)

Wainimala Group (Late Oligocene, Early and Middle Miocene)

(Sawa-i-lau group only, off SW Yasawa)
Sawa-i-lau Limestone (massive limestone; Middle Miocene)
Verona Formation (fragmental, sandstone to rudite, including beds of staghorn-coral rudite; Middle Miocene)
Sarona Andesite (breccia, lamprobolite andesite)

(Waya and islands to the south)
Tari Formation (breccia and sandstone, mixed compositions)
Nabu Formation (calcarenite and calcareous sandstone and fine-grained breccia)
Dakadaka Basalt (pillow lava, breccia, beds of calcarenite)
Kalaka Dacite (fine-grained tuff to breccia, Malolo and Malolosewa only)

Intrusive rocks
Drawaqa Gabbro (Late Miocene; largely porphyritic microgabbro)
Andesite of White Rock (hornblende andesite, 8 Ma)

YVG formations are widespread and are not restricted to the areas given above.

Route

Four sand cays in Nadi Waters: Tai (Beachcomber Resort, Fig. 5), Luvuka (Treasure Island Resort), Kadavu (Bounty Resort), Vunivadra (South Seas Island Resort)

Vomo – Loto Basalt overlain by Vomo Andesite; extensive sand flat

1 Kuata – Monu Dacite of the Kuata Volcano, some andesite

2 Wayasewa?

3 Wayasewa – Dakadaka Basalt overlain by Tari Formation (the peak Vatuvula, Fig. 14) and to the east, Bukama Dacite forming the point – the magnificent bench and notch should be visible (Fig. 6); Namara appears to be in danger from landslides, but is actually fairly well protected by a spur; large blocks from old slides can be seen at each end of the village; on the way to Waya the spectacular dip-slope of Vatunareba will be seen (Fig. 2)

4 Northwestern Waya – Nalauwaki Andesite with intercalations of Monu Dacite (the intercalations of the Loto Basalt and Vomo Andesite will not be visible)

5 Viwa – emerged reefs, one at 6-8 m AMSL dated at about 130 ka

6 Naukacuvu – Bukama Dacite including minor hornblende-andesite crystal tuff presumably from Waya

7 Nanuya Balavu – Bukama Dacite intruded by Drawaqa Gabbro; also breccia of the Cosiga Pillow Lavas which caused disturbance forming a deposit of blocks of dacite tuff (Fig. 16)

8 Drawaqa – Bukama Dacite intruded by Drawaqa Gabbro

9 Western Naviti – mostly Cosiga Pillow Lavas, but there are small patches of the Nato (subaerial) Basalt

10 NW Naviti – Cosiga Pillow Lavas; the offshore islet Nanuyanikucuve (island of rats) is formed of pillow lava with some hydroclastic rocks (Cosiga Pillow Lavas and Drola Hydroclastites)

11 NW Naviti – Cosiga Pillow Lavas; on the way to Namatayalevu the limestone mass on SW Yaqeta can be seen, with scree forming two headlands below it

12 Namatayalevu, Yaqeta – Nato Basalt intruded by feeder dyke swarm on the west coast

I suspect that the route I have been given is slightly in error here

13 Southern Matacawalevu – Nato Basalt intruded by Drawaqa Gabbro; to the north is a low sand ridge, an old tombolo, rising to 2.7 m AMSL, built on an old beach

14 Vuaki, Matacawalevu – Nato Basalt, partly altered; extensive sand flat dries at low tide for more than 500 m from shore, as does another on the south coast, this ranging from about -0.7 to -0.3 m AMSL

Confusing from here on. Nanuyalevu (Turtle Island Resort) and Nanuyasewa – Nato Basalt

Tavewa – Drola Hydroclastites (Fig. 20) with feeder dyke swarm, but possibly subaerial (Nato Basalt) in the south

SW Nacula – Nato Basalt

Nacula village? Nato Basalt well exposed on the islet Digio, and feeder dyke swarm on Namu Point to the west

Figure 1. The punt *Argo*, used for the mapping in 1969 and 1970; at Natia, Viwa.

PHYSIOGRAPHY

The islands of the study area can conveniently be divided into four physiographic subdivisions: the main chain of islands comprising the Yasawa, Narokorokoyawa, Mamanuca and Malolo Groups; Yalewa Kalou; the Viwa cluster; and the islands in Nadi Waters. All subdivisions are quite different apart from the three high islands in Nadi Waters, which are similar to the islands of the Yasawa-Malolo chain and belong geologically to that chain. The varied topography reflects the age and geological structure.

Yasawa-Malolo chain

A large submarine plain, mostly with low relief but up to 100 m where reefs reach the surface, stretches west and northwest from Viti Levu, and the Yasawa-Malolo chain represents an emergent ridge of mountains and hills, with the submarine plain continuing for a variable distance further west. Even the low northeastern end of Yasawa reaches almost as high above the sea as the submarine plain lies below the surface. The ridge continues well past Nanuya-i-yata, only descending below the 10-m bathymetric contour 8 km northeast of that island (though there are channels between islands which are more than 10 m deep), and descending below 50 m about 3 km further northeast.

Virtually all the rocks of the chain are volcanic in origin, and the islands are in general rugged. The islands south of the Yasawa Group (i.e., south of Kuata) are mainly small and each has a single main peak, but Waya and the larger islands northwards along the chain are more varied, with multiple peaks. The geological structure is basically a monocline dipping towards Viti Levu, and the shapes of the islands reflect this to some extent, the higher peaks being northwesterly of the centres of the islands. The larger islands gradually decrease in height (Table 3) from Waya (571 m) towards Yasawa (maximum elevation 233 m), and in general also decrease in breadth (Table 5).

Table 3. Major islands of the Yasawa Group in order of height (m).

Waya	571.2
Naviti	387.7
Wayasewa	353.6
Matacawalevu	300
Nacula	270
Yasawa	233.2
Yaqeta	220.1

Table 4. Major islands of the Yasawa Group in order of size (km^2).

Naviti	33.99
Yasawa	31.48
Waya	22.0
Nacula	21.7
Matacawalevu	9.50
Yaqeta	7.30
Wayasewa	6.41

Table 5. Major islands of the Yasawa Group in order of maximum breadth (km).

Waya	6
Naviti	5
Nacula	3
Matacawalevu	3
Wayasewa	3
Yaqeta	2
Yasawa	2 (9 km at the SW hook)

Waya in plan resembles a very bold H and consists of two main parts, the uprights of the H, this largely reflecting the geology and structure. Each of the parts is basically a monocline dipping at 20-30^o east. The eastern half is much older than the rest, and rises to various peaks some of which consist of younger rock, but largely approximates a dip slope on the older rocks. The southern part of the western half is a magnificent dip slope rising from the sea to just over 500 m elevation at Vatunareba; the northwestern part has subdued topography. The Vatunareba dip slope is not a continuous plane, being broken by ravines following joints. However, viewed from the south, a single plane is seen, dipping at 26^o (Fig. 2). The scarp slope is partly vertical, the average slope from Vatunareba being 40^o; possibly much of the lower-gradient slope is scree. This dip slope is unmatched elsewhere in Fiji.

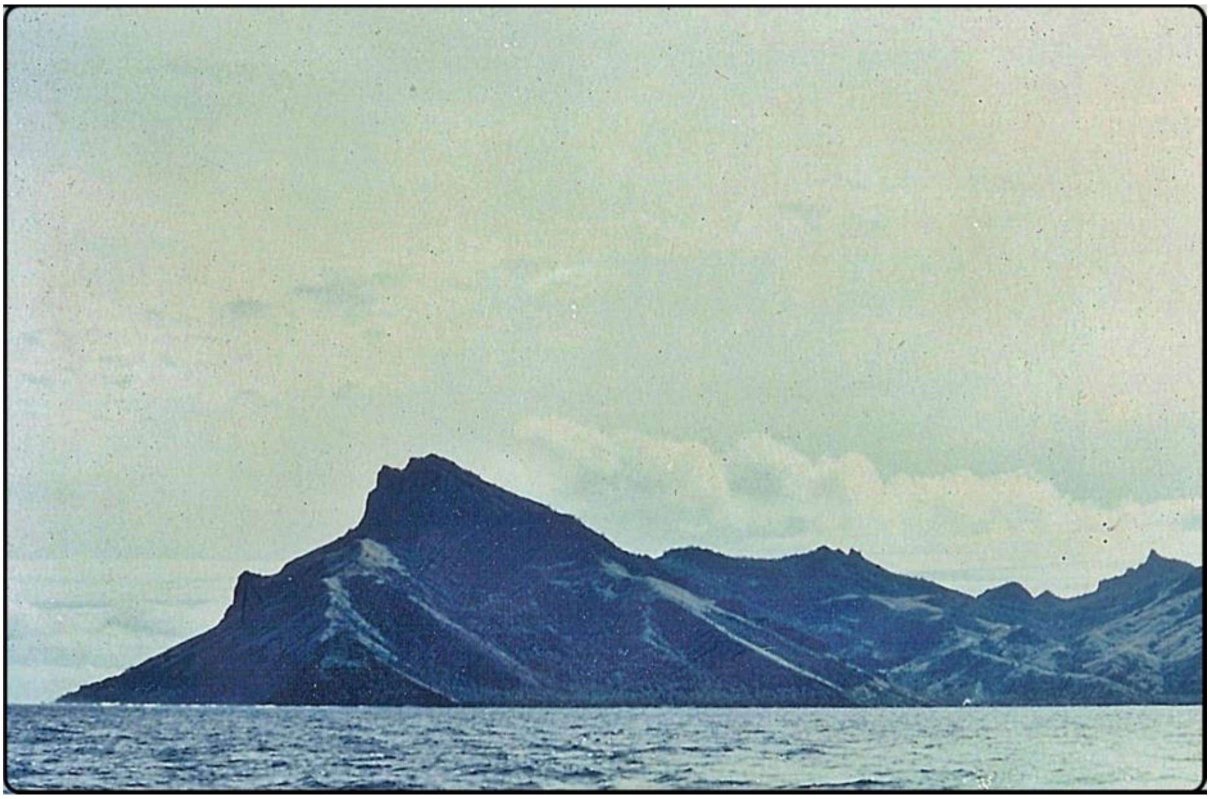


Figure 2. The Vatunareba dip slope seen from the south; the smoke is rising from Yalobi at the head of Yalobi Bay, with the Waya Postal agency prominent beside the plume.

Naviti, too, somewhat resembles the letter H but in very elongate form. It rises to a pair of rounded peaks resembling volcanic plugs which however are merely erosional remnants of a pillow-lava unit. From this peak there are two diverging main ridges running southwesterly and two running northeasterly.

Yaqeta, Nanuyalevu, Nanuyasewa and Tavewa are fairly normal islands, but Matacawalevu has two main parts, south and north, each with the main peak near the west coast. There is a large bay between the two sections, surely eroded along faults running roughly west-east.

Nacula has three main sections, south, central and northern, almost separated by Vagadra and Drola Bays in the east and Malakati Bay in the west. The northern and central parts are separated by a major fault. The highest peaks rise a little above a narrow high plateau on the western side of the northern part of the island, but considerable peaks occur in the north and west of southern Nacula. There are two peaks in central Nacula.

Yasawa is a puzzle. It is basically a very elongate linear island, 22½ km long and ranging from 2½ km to 500 m wide. However, the northeastern and southwestern ends have a large “hook” each in plan. Much of Yasawa has the appearance of being only half an island, in that the watershed is at the top of coastal cliffs instead of being somewhat central. This is the case for much of the northwestern coast; taken with the shape of the island in plan, the suggestion is of much of the northwestern part of a very elongated oval island having been somehow gouged out, leaving the southeastern side and the two curved ends.

The explanation that jumps to mind is that this is a reflection of geological structure, of something approximating to a dip slope, with a scarp slope falling to the sea, as in southwestern Waya with its dip slope and steep scarp slope. Elsewhere in the Yasawa Group, too, watersheds are offset from the centres of elongate islands, approximating dip and scarp slopes (parts of Matacawalevu, Yaqeta and Naviti). This interpretation is in fact correct for part of the length of Yasawa, for instance the short stretch of coast from Naloto Point southwestwards, where the gentler slopes follow the direction of dip down to a synclinal axis (though the beds dip much more steeply than the topography), and in other places such as opposite Cikia Reef and at Nasawalevu and Yadrayadra Points. Similar topography, the watershed occurring at the tops of cliffs, also occurs at the northern tip of Nacula and consists of an approximate dip slope and scarp slope.

However, in most places on Yasawa the gentler slope is certainly not a dip slope, for instance in the far southwest from Koroiratuna Point to Naivatikidro ("Rock Pt") where the dip is either roughly parallel to the coast (Naivatikidro itself, Figure 3, consists of a dip slope and scarp slope) or opposite that of a dip slope. Again, in the northeast from Votua southeastwards, the beds are mostly close to vertical and in fact are interpreted as forming an isoclinal syncline roughly midway down the gentler slope.

Figure 3. Naivatikidro, southwestern Yasawa, showing dip and scarp slopes striking normal to the coast; taken from the watershed at the top of the cliff.

The only explanation that seems likely is that there has been extensive block faulting combined with local strong control of erosion by lithology. Lithological control of erosion is well seen in the area of Naloto Point where the synclinal axis is occupied by pillow lava, and perhaps in the southwest where a possible anticline core is occupied by Namataya Bay.

Joints control the shape of Nanuya-i-yata (northeast of Yasawa) – Figure 4.

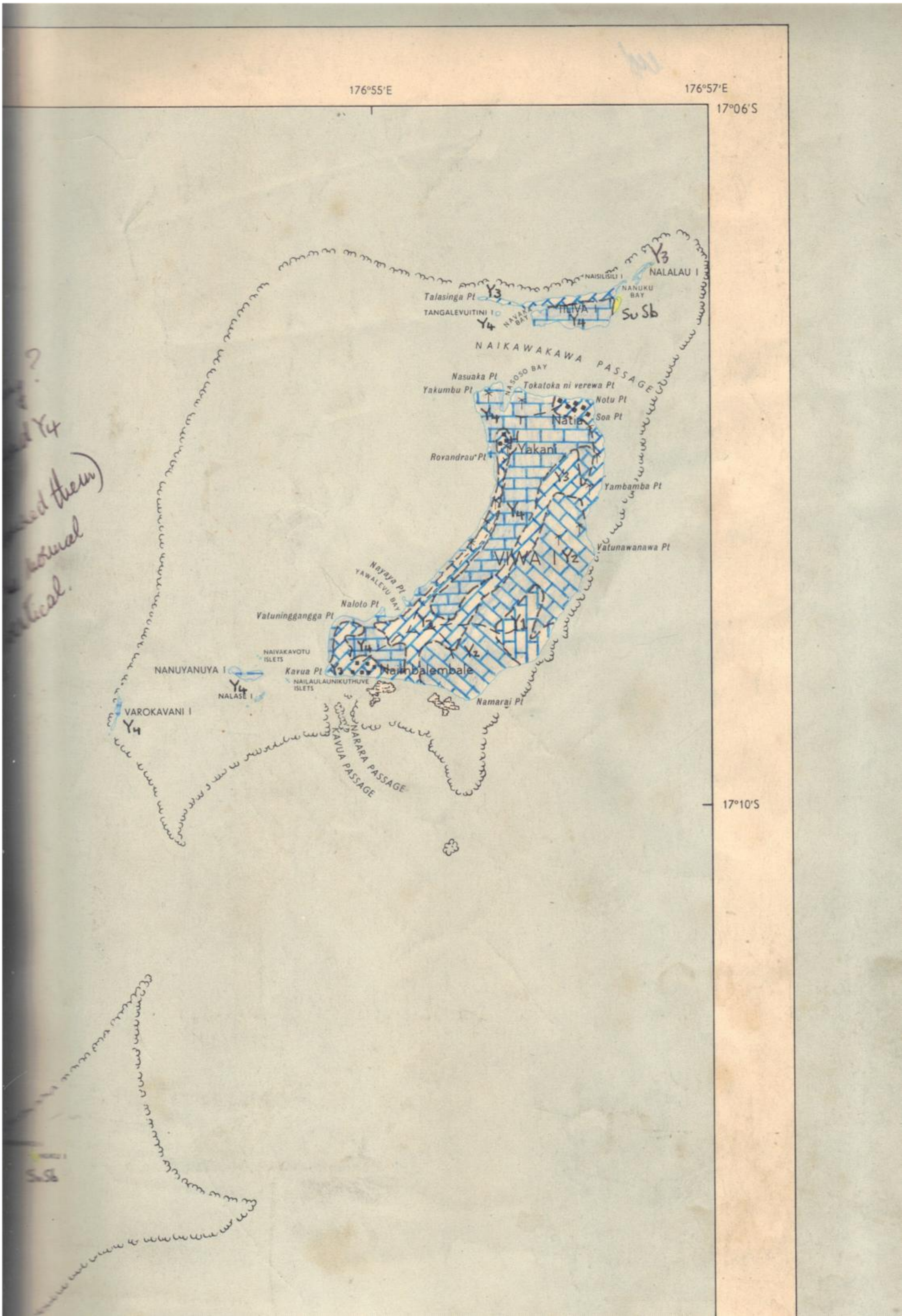
Figure 4. Joints controlling the south coast of Nanuya-i-yata
(two black spots at right are flaws on the negative).

The Viwa cluster

Viwa is a long, low island. Together with its satellites Tiliva and the islands west to Varokavani, it forms a group 8 km long and 4 km wide, rising to a maximum of 18-19 m AMSL. All the islands and islets are composed of reef limestone. Some distance to the south is an atoll, somewhat smaller than the Viwa reef system, with two islets – Nuku (“sand”), within the lagoon, composed wholly of beach-rock and a small amount of sand, and Nukuvatu (“sand-rock”), emerged reef limestone rising from the western part of the present reef (this is the westernmost island in the Fiji archipelago). All the limestone islands are flat topped and within the group three surfaces, apparently level, are obvious. The lowest, 2-3 m AMSL, is developed on parts of Tiliva and Viwa, and throughout all the islets to the southwest, except for one pinnacle on Varokavani which rises to about 4½ m AMSL. The middle level, about 6 m AMSL, is seen on northern Tiliva, much of Viwa, and Nukuvatu. F.W. Taylor (1978) noted, at one place on the east coast of Viwa, above a cliff rising to 7 m AMSL, a second cliff (rising to 11½ m AMSL) with a marine notch at its base, about 7½ m AMSL. The highest level exists only on eastern Viwa, where an extensive area lies at an elevation of 15 to 19 m AMSL. There is also a possible remnant of a surface at about 10-12 m; the cliff mentioned above, rising to 11½ AMSL, is supporting evidence. These levels suggest a history of intermittent emergence, with periods of stability when reefs were built outwards from the new coasts, and shore platforms were possibly formed. Beach-rock may also have formed as well, on some of the new coasts. The curve of the south coast of Viwa and the arc of islets to the west roughly follow the curve of the southern part of the barrier reef. It is thought that all the islands within the Viwa reef were originally part of Viwa, and have been separated from Viwa by erosion.

Figure 4a. Islets off Nabalebale, Viwa.

Figure 4b. *Talatala*'s house at Natia, northern Viwa, showing terrace 2-3 m AMSL and marine notch.



176°55'E
176°57'E
17°06'S
17°10'S
NAISILISILI I
NALALAU I
NANUKU BAY
Talasinga Pt
TANGALEVUITINI I
Y3
Y4
Su Sb
NAIKAWAKAWA PASSAGE
Nasuaka Pt
NASOSO BAY
Tokatoka ni verewa Pt
Yakumbu Pt
Notu Pt
Natia
Soa Pt
Yakani
Rovandrau Pt
Yambamba Pt
Vatunawanawa Pt
VIWA I
Y2
Y1
Nayaya Pt
YAWALEVU BAY
Naloto Pt
Vatuninggangga Pt
NAIVAKAVOTU ISLETS
NANUYANUYA I
Kavua Pt
Naimbalembale
NAILAULAUNIKUTHUVE ISLETS
NALASE I
Namarai Pt
VAROKAVANI I
NARARA PASSAGE
KAVUA PASSAGE

Islands in Nadi Waters

All the islands within the curve of the Yasawa-Malolo chain are simple sand cays (Fig. 5), other than Vomo and Vomo Lailai and White Rock. The sand cays, which mostly have some beach-rock, rise to only a few metres above sea level. The Vomo islands are volcanic in origin and are fairly rugged (apart from an extensive sand flat in western Vomo), whilst White Rock is an elongate rounded hump of intrusive hornblende andesite with a minimal beach in the southeast. The basement for the sand is not known for any cay, but it was said that an exploratory bore on Kadavu reached weathered rock (not coral).

Figure 5. Tai, a sand cay typical of those in Nadi Waters
(the fact that it has a resort is also now typical).

Coastal features

Shore platforms cut in bedrock are very common, some stretching out for 50 m and more from the shore. Most appear to be about mean sea level. Elevations of only a few have been measured; the highest is that not far west of the northern tip of Nacula, lying at +0.5 m AMSL. Three on Yasawa are within about 0.1 m of mean sea level.

There are extensive reef flats covered with sand between tide levels in some places. Part of the string of islets off northeastern Naviti, from Ori south to Nanuyavunivau, are joined to Naviti by one. Another is along the eastern side of Matacawalevu between Tokolevu and Sonilawe Points, and a third joins Nanuya and Sawa-i-lau to Yasawa at Nabukeru.

Benches are also very common, and all appear to be typical abrasion benches. Measurements have been made on 137 benches (plus others, of low accuracy or on benches recorded as being minor), and by far the most common elevation is about +0.9 m AMSL (19 measurements), with 45 measurements in the range +0.8 to +1.0 m AMSL. There is commonly a raised rim on the seaward side. A marine notch is commonly well developed and profiles of some were illustrated by Rodda (1991).

Figure 6 shows a superb bench and notch in southeastern Wayasewa, and Figure 7 shows a wide bench at several levels, and notch of different profile, south of Koromasoli Point in northeastern Waya.

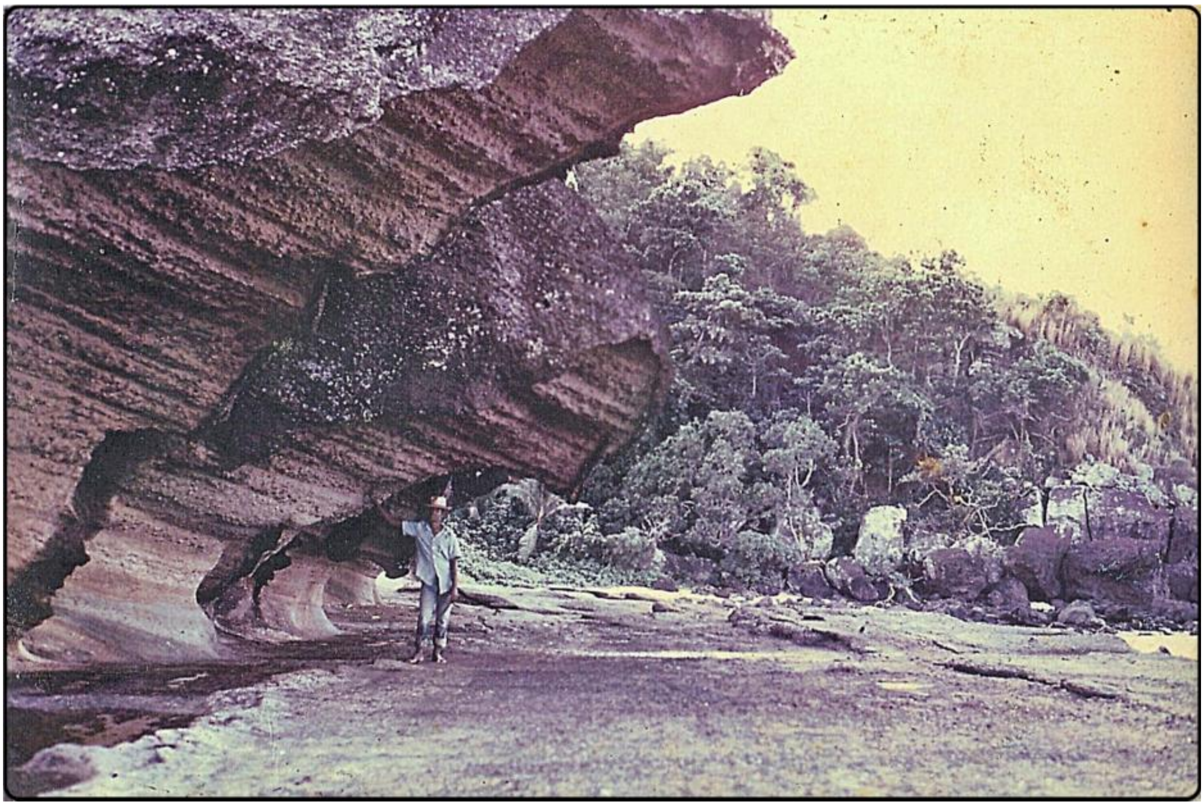


Figure 6. Naqalia Point, southeastern Wayasewa, showing bench and notch cut in dacite tuff and lapillistone (Bukama Dacite).

Figure 7. Coast of Waya south of Koromasoli Point, showing bench at various levels and high notch, cut in vertical beds of the Koromasoli Sandstone; looking northerly.

Sand dunes or beach ridges occur scattered throughout the Yasawa-Malolo chain. On the north coast of northeastern Naviti the dune behind the beach rises to +11.7 m AMSL. Other places in which beach ridges or dunes were noted include central Yanuya and the southeast coast of Yasawa on both sides of Bukama. There are deposits of sand which would no doubt have formed dunes had they not had a steep slope adjacent, in northern Yasawa, where sand has been blown up into a pile +13 m AMSL east of Qereqere Point and at Yaduvutuna Point on the southeast coast not far south, where a pile was estimated at perhaps 20 m AMSL.

Weathering

Some interesting coastal forms of weathering occur. Well above the shore, the weathering produces somewhat smooth surfaces with clasts protruding, but in the shore zone (up to 6-10 m above sea level) there appears to be case hardening. This affects mostly the matrix, but in some places apparently also the rims of some clasts; coastal exposures are therefore commonly smooth (and black). Most of the clasts in the shore zone weather more quickly, producing large-scale honeycomb weathering surfaces. A further stage is reached, presumably when the weathering of clasts has penetrated the hardened exterior of an outcrop, in which a large hollow (a tafone) is formed in the outcrop and erosion of the matrix begins. Where this has happened, most clasts protrude from the matrix (though some weather at the same rate). Hollowed-out float blocks occur, in which one half of the hardened case remains but almost all of the remainder of the block has been eroded; the convex side shows honeycomb structure whereas the concave side is knobbly, with the clasts protruding from the matrix. The thickness of the hardened layer is as much as 0.3 m thick in places, though examples have been seen which are as little as 2½ cm thick, but this could be the result of erosion from a thicker layer. These hollows (tafoni), however, were later noted on Kuata up to great heights, showing that this is not a shoreline feature related to seawater, but could have been formed by windborne salt.

Windborne salt probably plays a part in weathering. On a traverse up the steep northwestern side of Yasawa opposite Nabukeru, many fresh outcrops were found, contrasting with much greater weathering on the gentle slopes down to the village. Salt spray was noticeable in the strong wind, and this might be partly to blame. During hurricanes it is common for so much salt spray to be blown up that it kills much of the grass. It is likely, however, that the weathering contrast between the steep hillside and the gentle slopes is partly due to the varied speed of sheet runoff during heavy rain.

STRATIGRAPHY

Wainimala Group

Rocks of the Wainimala Group make up most of the Malolo Group, much of the Mamanuca and Narokorokoyawa Groups, Wayasewa and eastern Waya. They are an extension of the rocks of the Wainimala island-arc sequence exposed in much of southern Viti Levu, and, with a discontinuity in the Mamanuca Group, continue its structure. Breccia of andesite and basalt, and limestone, also occur in the far north of the Yasawa Group, forming Sawa-i-lau and its neighbouring islets and Verona; this appears to be a thrust block similar to that of Narosalia to the northeast.

The oldest rocks of the group are probably those of the Dakadaka Basalt, which are the lowest exposed on the islands of the Mamanuca and Narokorokoyawa Groups, Wayasewa and Waya. The age relationship between these and the dacitic rocks (Kalaka Dacite) forming much of the Malolo Group is not visible. The age of the Sarona Andesite of Sawa-i-lau and Verona is unknown, but the rocks might be interbedded with those of the overlying Verona Formation, which is no older than late Early Miocene, considerably younger than the Dakadaka Basalt.

On Waya and Wayasewa the Dakadaka Basalt is overlain by the Tari Formation, whilst on Eori the overlying rocks belong to the Nabu Formation. In the north, the Sawa-i-lau Limestone overlies the Sarona Andesite and probably also the Verona Formation, though the Sawa-i-lau Limestone and the Verona Formation have nowhere been seen in contact.

Dakadaka Basalt

The rocks of this formation in the area of study are almost wholly pillow lava and breccia, with rare massive flows on Tokoriki and subordinate sandstone on Waya. The sequence is wholly submarine, but the rocks in the northeast of Tokoriki appear to be hydroclastic and shallow-water in origin.

The matrix of the pillow lava (on Waya, Wayasewa, Eori, Navadra, Kadomo and Tokoriki) is commonly pink to red limestone, calcarenite to calcilutite but in some places grit, some containing planktonic foraminifera. In exposures much of this matrix is green or yellow, for instance on Navadra and Eori. Epidote was seen as matrix of pillows in float on Kadomo and of breccia on Eori.

The pillows are usually in the range 0.6 to 1.2 m in diameter on Tokoriki; on Eori in one place they were noted as being 0.3 to 1 m in diameter, and at Lovoni north of Wayalevu and also south of the village, 0.3 to 0.6 m. Figure 8 shows pillow lava at Motukuro Point on Waya. There is no equivalent of the large-pillow lava that is so common in the Cosiga Pillow Lavas of the Yasawa Volcanic Group. The largest pillows noted are at Motukuro Point where they reach 2 m long, and in northeastern Navadra, where there are elongate pillows up to about 3½ m long and 1½ m in diameter.

Figure 8. Pillow Lava of the Dakadaka Basalt, Motukuro Point, eastern Waya.

Figure 9. Breccia within the Dakadaka Basalt, north end of Lovoni beach, north of Natawa, southeastern Waya.

An intriguing structure, of interlayered basalt and red limestone, occurs on the north side of Eori. Basalt and red-brown gritty calcilutite are regularly interlayered, layers of limestone being 1-5 cm thick and the basalt 5-7 cm thick (Figs 10, 11). The layers undulate. This is within a thick pillow-lava unit. Similar interlayering occurs south of Liku beach on Kadomo, the layers being 3-8 cm thick, and just south of Wayalevu in northeastern Waya. In this latter locality, the limestone layers are 1-2½ cm and layers of lava are 2½-8 cm thick. As on Eori, this is within a pillow-lava unit. There are 12-15 lava layers. Some of the pillow matrix nearby is green sandstone/grit, now very crumbly. The origin of this type of structure is problematic; on Kadomo, perhaps a block of lava split while moving down a submarine slope of lime sand, but the regularity of thickness of the basalt slabs is intriguing.

Figure 10. Interlayering of calcilutite and basalt; north coast of Eori, Narokorokoyawa Group; the veins at the upper right are of zeolite.

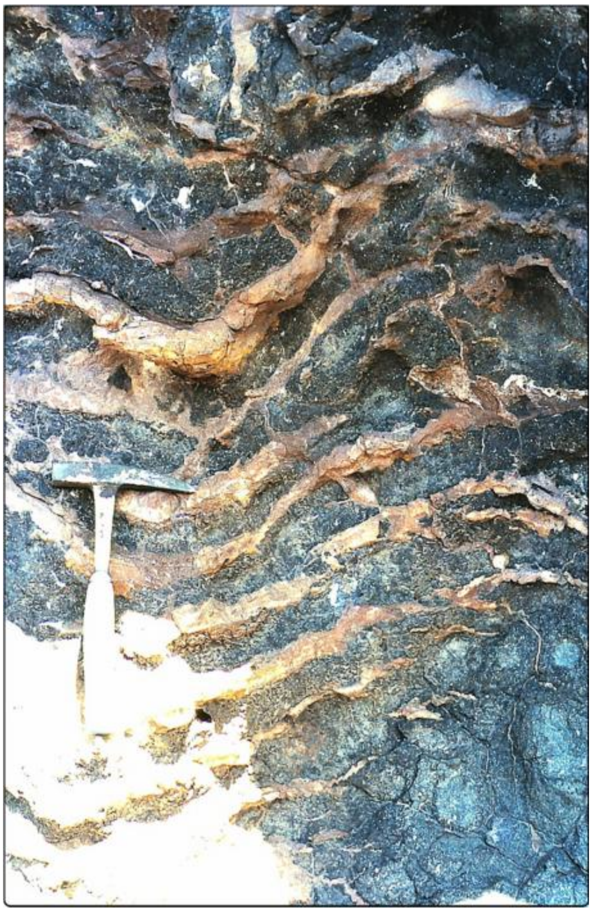


Figure 11. Detail of Figure 10.

The basalt of the pillows and breccia clasts usually has feldspar phenocrysts, and augite is sometimes visible. In places there are common pseudomorphs of red-brown smectite-chlorite after olivine.

Basalt dykes are common in the Dakadaka sequence on Waya, Wayasewa, Navadra and Kadomo. On Tokoriki and Tavua they are subordinate to andesite dykes (and on Tavua, dacite dykes occur as well). Some of them are obviously contemporaneous with the lavas and breccia, having irregular margins which are indented by breccia clasts or protrude to fill interpillow spaces. Good examples of such dykes occur in northeastern Tokoriki and on Waya at Motukuro Point. The thicknesses of dykes vary considerably but a general average thickness seems to be half to one metre. In eastern Waya, for instance, 166 dykes with measured thicknesses total 271.1 m; the range is 0.13 m to 35 m. Just north of Naikawakawa, dykes in a swarm of perhaps 35, all about the same strike, range from 0.20 to 0.70 m; near Natawa, one set of 30 dykes was measured, totalling 14.4 m, average 0.5 m, range 0.13 m to 1.2 m. These two examples indicate that a meaningful average would be less than 1 m.

The dykes predominantly strike parallel to the strike of the strata and are assumed to represent the feeder system for the basaltic eruptions.

Nabu Formation

Only on Eori is there a sequence of strata assignable to the Nabu Formation that is large enough to show as an area on the 1:50 000 map.

The extreme eastern tip of Eori has red calcarenite churned up in Dakadaka basaltic breccia (Fig. 12). Above is thin-bedded calcarenite, pale blue-green weathering to yellow, forming the matrix to rudite and possible pillow lava. Most strata higher in the sequence are sandstone (Fig. 13), medium grained (some) to fine grained, chocolate to red-brown and orange-brown, rarely grey-green, intensely bioturbated, and some parts are very like the strata at Yalobi (see below). The sandstone is very thin bedded, the mudstone is laminated. Some beds are conglomerate of small pebbles of fine-grained ?sediments and volcanics – red, brown, green – and limestone containing larger foraminifera, with grit matrix.

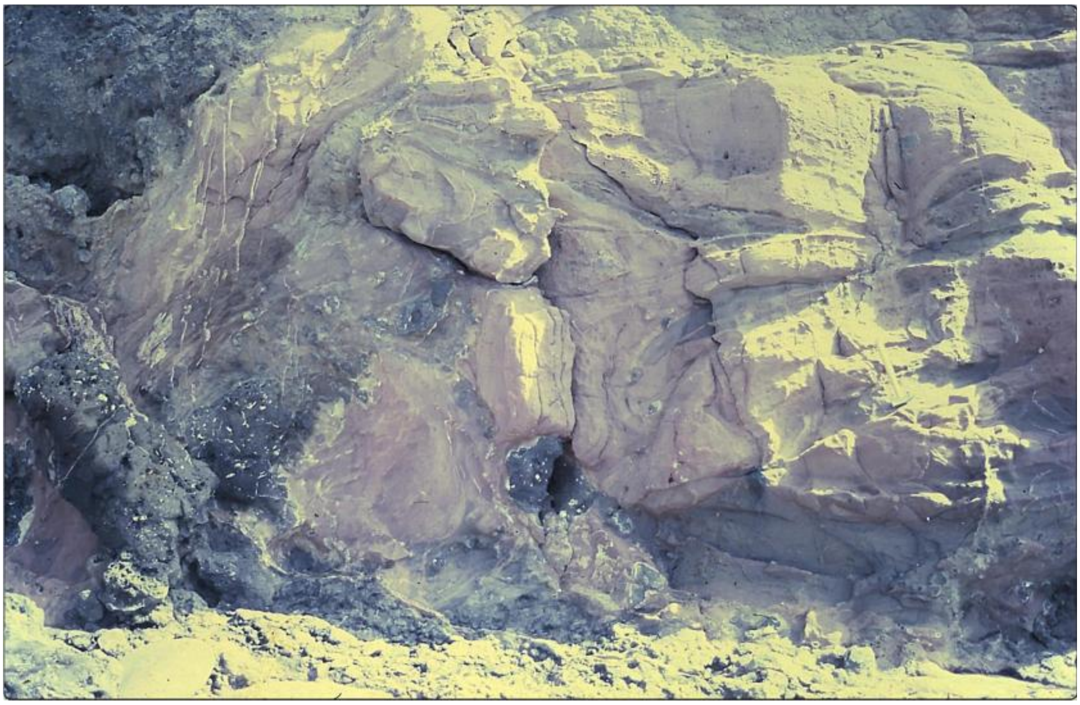


Figure 12. Calcarenite (Nabu Formation) churned up by the arrival of basalt which formed the overlying pillow lava (Dakadaka Basalt); east end of Eori, Narokorokoyawa Group.

Figure 13. Well-bedded calcarenite; near Fig. 12.

Tari Formation

The Tari Formation is mainly volcaniclastic rudite (and in Viti Levu, has subsidiary lava flows, thin-bedded sandstone and mudstone, and limestone as well). The clasts are of variable composition. In the Yasawa Group, rudites correlatable with the formation form the highest ground in eastern Waya and southern Wayasewa. The rocks are relatively hard and produce striking peaks and pinnacles which resemble volcanic plugs, for instance Ulutunayau southwest of Wayalevu and Vatuvula above Namara. No flows have been seen, nor any sequences of sandstone or mudstone, and there is no limestone.

Figure 14. View of Wayasewa from Kuata, with Koroyanitu on Viti Levu on the skyline. The peak on Kuata is of dacite breccia (Monu Dacite) but the rock mass Vatuvula on Wayasewa (above Namara village) is of breccia of the Tari Formation; the easterly slope of Wayasewa approximates a dip slope, and the exposed rock mass east of Vatuvula is also Tari breccia. Photo: S. Birch

Buckle (1988) noted that in the Tari Formation in the headwaters of Wailevu and Natogo Creek there are no penetrating structures such as the dykes and faults that are so common in the Dakadaka Basalt; nor were any dykes found in the extensive area of the Tari Formation that the present author traversed on Wayasewa.

Sarona Andesite, Verona Formation, Sawa-i-lau Limestone occur only on Sawa-i-lai and adjacent islands,

Kalaka Dacite

The Kalaka Dacite occurs only in the Malolo Group, on Malolo itself and Wadigi. All other dacites nearby are thought to belong to the much younger Monu Dacite of the Yasawa Volcanic Group.

Yasawa Volcanic Group

Formations not occurring on islands along the route of the excursion are omitted.

The Yasawa Volcanic Group comprises a thick sequence of submarine rocks overlain by hydroclastic and subaerial rocks. A relatively large number of formations are seen in stratigraphic relationship in three areas, on and around Yasawa itself, in western Waya and on Yanuya in the Mamanuca Group. On and around Yasawa, the oldest rocks exposed are dacite tuff of the Bukama Dacite, overlain by and interlayered with the Cosiga Pillow Lavas, which grades upwards and probably also laterally into the Nabukeru Breccia and the Naitataniika Sandstone. In eastern Waya, dacitic rocks disconformably overlie rocks of the Wainimala Group, whilst in the western half of the island the lowest strata are assigned to the Nalauwaki Andesite, which grades laterally eastwards into the Koromasoli Sandstone, and includes a unit of dacite breccia, and the Loto Basalt and Vomo Andesite as wedges. The central part of the Yasawa chain is occupied by subaerial rocks which appear to be in general younger than the submarine sequences and compose the Nato Basalt, with an intermediate zone of hydroclastic rocks – the Drola Hydroclastites. On Yanuya the lowest rocks exposed are assigned to the Nalauwaki Andesite, and are overlain by rapidly alternating rock-types of the Monu Dacite, the Cosiga Pillow Lavas and the Drola Hydroclastites and possibly also the Nato Basalt.

There is therefore no simple stratigraphic sequence other than the general trend of dacitic rocks and basaltic pillow lavas at the base, grading upwards into breccia and sandstone and the hydroclastic and subaerial rocks, with the aforementioned lateral facies changes.

Bukama Dacite

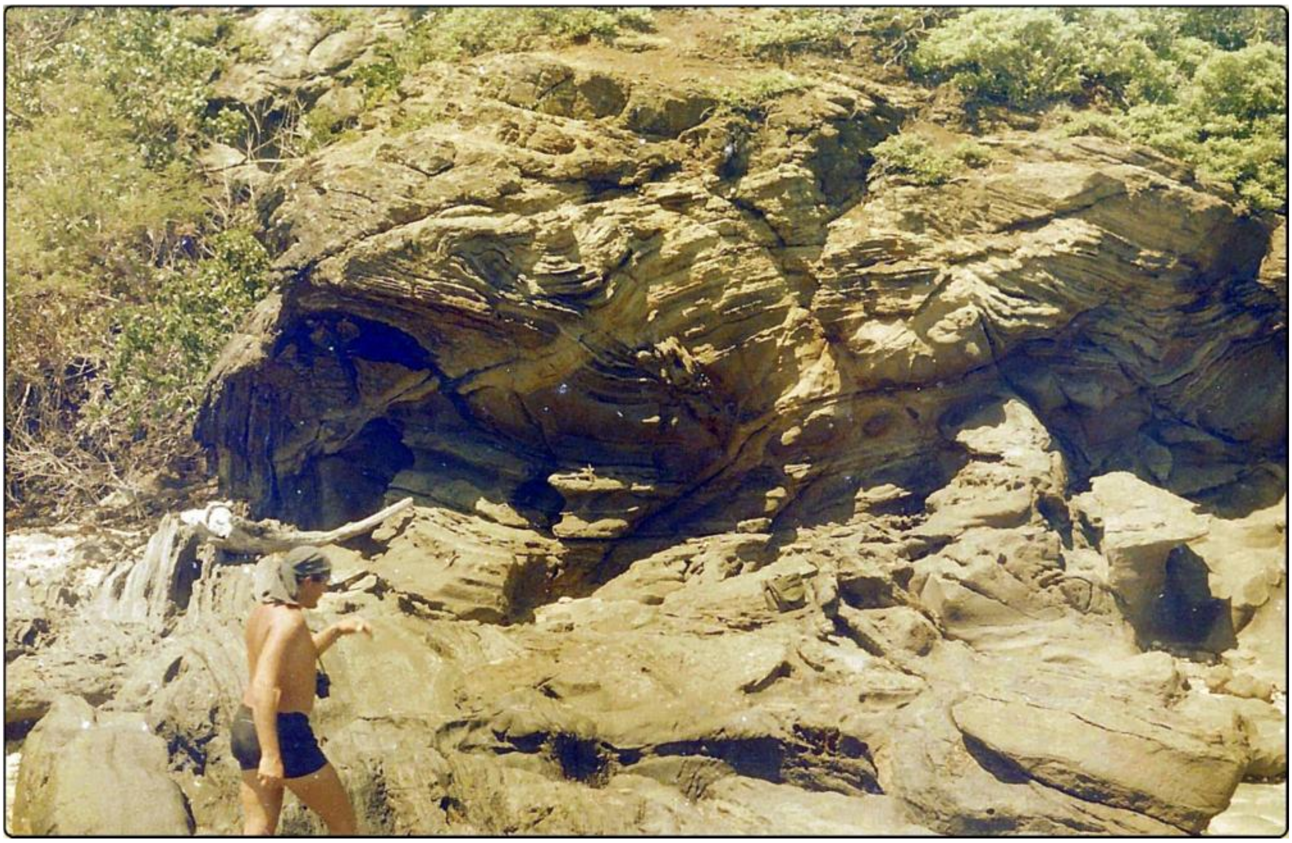
This formation consists essentially of lithic tuff, mostly fine grained, with minor lapillistone and rare pebble breccia, and occurs mainly in northern and central Yasawa and nearby islands/islets. Some dacite “ignimbrite”, about granule grade, with glass shards up to 1-2 cm long in places, occurs in the Namulo Bay area. Coarse crystal tuff occurs on Nanuya-i-yata. Two main types of tuff are assigned to the formation. At the type section and in most other parts of Yasawa and adjacent islets the tuff is fine grained (mainly of mudstone grade) and commonly a distinctive turquoise green, or yellowish, also shades of red to purplish. The strata of southwestern Naviti and the islets to the south are coarser (mainly of sandstone grade) and commonly brown or grey, but the finer-grained green and reddish varieties occur, being particularly common on Narara, and red beds are particularly common.

A beautiful contortion of beds, also presumably caused by sliding, occurs in southeastern Wayasewa in a sequence of tuff. In this case the sliding was of a (huge?) slab of sediment, still nicely bedded, lubricated by a thin sequence underlying it, which was folded and contorted giving a concertina effect (Fig. 15).

Figure 15. Crumpled dacite tuff, presumed to be the result of sliding of the sediment (now eroded away) above the crumpled unit.

A slump deposit is also visible near the northern tip of Nanuya Balavu (southwest of Naviti). This could have been caused by a lahar of basaltic detritus which was deposited unconformably on this slump deposit.

Figure 16. Slump deposit of dacite tuff (Bukama Dacite) near the northern tip of Nanuya Balavu; the vertically bedded mass at bottom left is about a metre in thickness.



Bonus photo which will not be included in the final version because of the spoilt colour (the negative deteriorated and I do not have a print made before that).

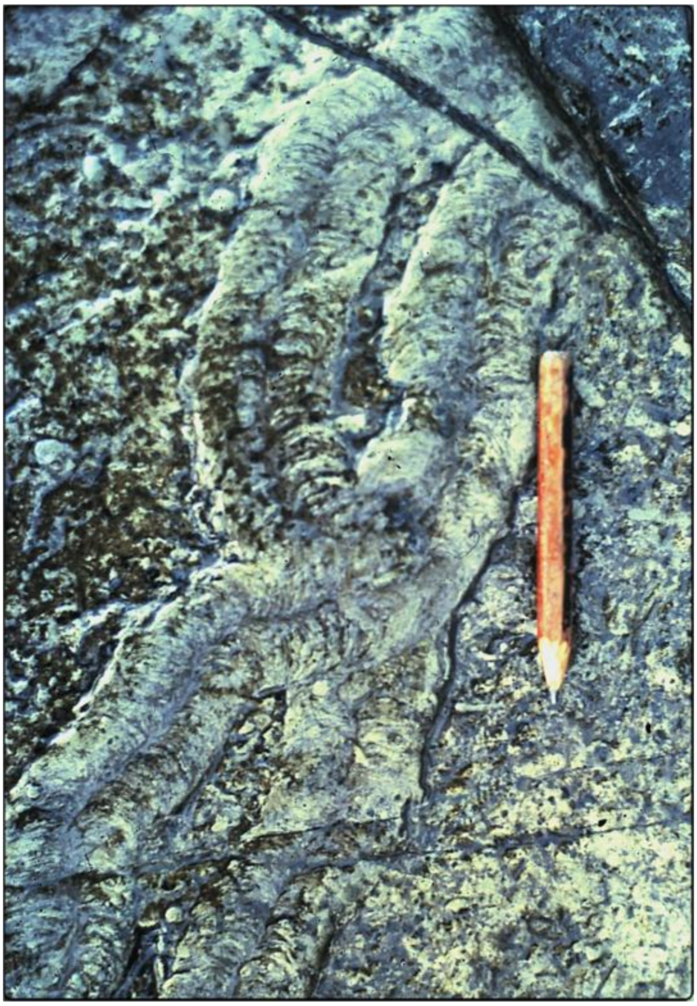


Figure 17. Trace fossil in dacite tuff (Bukama Dacite), Narara.

Metasomatic knobs are common adjoining gabbro sills on the four large islets south of Naviti (see under Drawaqa Gabbro).

Cosiga Pillow Lavas

The Cosiga Pillow Lavas, comprising basaltic pillow lavas and associated autobreccia, rare pillow breccia, minor tuff and basaltic sills, is the most widespread of the formations in the Yasawa Volcanic Group. It occurs from Mana and Yanuya in the Mamanuca Group to Nanuya-i-ra northeast of Yasawa. It is best developed on Yasawa and Naviti.

The rocks making up the formation were apparently erupted largely from a fissure system parallel to the length of the island chain but located mainly northwest of the present islands. Basaltic dykes are dominantly sub-parallel to the island chain. They occur in swarms in the mainly subaerial basalts from northwestern Yaqeta through Matacawalevu and associated islands and Tavewa to northwestern Nacula, and in southwestern Yasawa where the rocks are submarine. In several places dykes are seen to have offshoots filling interpillow spaces, or wending their way between pillows, indicating intrusion of the dyke soon after pillow formation, before any sediment had a chance to fill the spaces.

Some lavas, however, were formed by sills breaking through to the sea floor. One such occurs on Nanuya-i-ra north of Yasawa, where a gabbro sill and a pillow lava occur very close together and the geometry hardly permits any other interpretation.

Figure 18. Pillow lava (Cosiga Pillow Lavas), Nanuya-i-ra (northeast of Yasawa).

The basalt of the lavas is usually either aphyric or rich in feldspar. Intermediate types are uncommon. Phenocrysts are of plagioclase and augite, in some places also olivine (now altered).

Monu Dacite

The Monu Dacite comprises mainly breccia, in contrast to the Bukama Dacite which is mainly tuff and the Matacawalevu Dacite which is flows and ignimbrite.

Monu Volcano Monuriki consists mainly of dacite breccia, with one possible flow seen; it ranges from cobble breccia with occasional blocks through pebble/cobble breccia to pebble breccia with some sandstone beds. Most large blocks are long slabs, and some are somewhat bent. No bedding is visible on a broad scale. The matrix is usually bedded siltstone and sandstone, but in one place it is quite hard and almost appears to be lava. The clasts are almost all to be described as green, in some cases pale yellow, especially in the notch (i.e. about sea level). Purple-red-brown clasts were noted in green matrix in one place each on Monuriki and Monu. The dacite has flow lamination and has scattered to common feldspar-lath phenocrysts; no quartz or hornblende was seen. Rare blocks of fresh glass occur, the largest noted being black/grey/green laminated glass with crumbly glass texture, 6½ m long and 2-3 m wide. One 3-m clast of this type is veined and weathered to a white powdery substance. On the bench which occurs along most of the coast, the rock is pitted where clasts weather faster than matrix.

Kuata Volcano Kuata consists almost wholly of fairly coarse dacitic breccia with occasional small intrusions, and is considered to represent a centre. On Wayasewa to the north there is a sequence of dacite tuff to lapillistone with quite a few syngenetic intrusions but that is assigned to the Bukama Dacite.

Waya The centre of eruption for the dacitic rocks of Waya is unknown, but could be in the vicinity of Windy Rock, off the northeastern point. Considering that the dacitic rocks on Wayasewa are mainly lapillistone and tuff (with intrusions), and are considered to be a facies distal to the central Kuata Volcano, it is unlikely that the strata on Waya, which are largely breccia, originated from the Kuata Volcano.

Nalauwaki Andesite

The Nalauwaki Andesite comprises a thick sequence of breccia and tuff, both largely reworked, of various rock-types but notably containing hornblende andesite, which makes up the western half of Waya. The common presence of hornblende andesite is the distinguishing feature of the formation. One probable flow occurs. Two intrusions are known, one largish plug in the centre of the island, and a smaller one near the west coast. The Cosiga Pillow Lavas, Monu Dacite, Loto Basalt and the Vomo Andesite occur as lenses or units within the Nalauwaki Andesite. Thin units of hornblende-andesite breccia and crystal tuff assigned to this formation occur on Naukacuvu to the north within a sequence of mainly dacite tuff (Bukama Dacite).

The sequence is mainly breccia, with subordinate conglomerate, grit and sandstone. Coral/algal clasts and clasts of crystal cumulates occur widely but apparently only in the younger strata east of Nalauwaki.

Loto Basalt

The Loto Basalt is defined at Loto Point, the southwesternmost point of Waya (shown on the DOS map as Loloto Point). It consists of unsorted block breccia of black to dark grey, somewhat glassy feldspar-phyric basalt with some augite and rare olivine, some fresh, some altered to smectite-chlorite. The occurrence of fresh olivine distinguishes rocks of the Loto Basalt from those of the Cosiga Pillow Lavas. Clasts are angular to sub-rounded, mainly up to about 0.3 m, but one 10-m block was seen, and others are more than a metre across. Most of the sequence here is cobble breccia with scattered to fairly common blocks. Matrix is minor. Perhaps 1-2% of the clasts are andesite, pale grey or red-brown. Some basalt is crowded with zeolite amygdales, suggesting possible pillow fragments. Rare finer beds occur, of pebble breccia with some cobbles, also sandstone, siltstone and grit, probably reworked tuff. Masses of interstitial chalcedony and rare agate occur in the breccia.

The Loto Basalt also occurs on Vomo, where it is presumably thicker than at Loto Point, because whilst the exposed thickness is about the same as at Loto Point, the base is not exposed.

Vomo Andesite

The Vomo Andesite is pyroxene andesite breccia composing Vomo Lailai and occurring on Vomo as a cap on the basaltic breccia forming the main mass of the island, and as a small knoll at the western tip of the sand flat. The breccia is orthobreccia, being usually close packed (clast supported). It is bedded on a large scale only, except for one thin sequence at least several metres thick of sandstone and pebble breccia. Much has only enough matrix to fill spaces but there is some parabreccia. The matrix on Vomo Lailai is usually white to off white, but in the cap on Vomo it is mainly yellow-brown, presumably andesitic palagonite, or brown tuff. All clasts are of the same rock, black pyroxene andesite ranging to pale grey, all somewhat glassy. The clasts weather to various colours normally also ranging from black to pale grey. There is some apparent polymict breccia, with clasts weathered to different colours, but fresh surfaces of the clasts all seem to be the same; the matrix is green. The clasts are all sizes, commonly 20-30 cm, whilst the matrix is sandstone in grade. There are blocks 1 to 4 m across in this sort of unit, and elsewhere there are beds with much smaller clasts (5-10 cm). Sparse clasts are layered. The knoll at the west end of Vomo is pebble to block breccia, chaotic, not quite orthobreccia - there is a fair amount of yellow-brown fine-grained pebble matrix. The cap on the main mass of Vomo is of massive to poorly bedded orthobreccia as seen on Vomo Lailai.

Pyroxene andesite also occurs on Waya, overlying breccia of olivine basalt (Loto Basalt) as it does on Vomo. However, there appears to be no unit of breccia of purely pyroxene andesite; other rock-types occur with the andesite.

Yavuriba also consists largely of pyroxene-andesite breccia and conglomerate. Much of the andesite is the typical black and semi-glassy type, but green varieties also occur. Some of the breccia has a green calcarenite matrix. Additionally, there are beds of glassy green tuff and of sandstone, some including foraminifera.

Koromasoli Sandstone

The Koromasoli Sandstone occurs only on Waya, and is the distal equivalent of the Nalauwaki Andesite. The andesitic rocks were apparently erupted west of Waya and the general grain-size decreases easterly. The sequence east of the syncline through the island is mainly sandstone, with subordinate mudstone and rudite which however increases westward (up sequence).

Koromasoli Point itself shows a sub-vertical sequence which consists mainly of calcareous fine-grained sandstone with siltstone, laminated to very thin bedded, with minor grit. Planktonic foraminifera are visible in many beds. Graded bedding, cross-bedding and other sedimentary structures are common. There is sub-horizontal faulting. Along the straight western side is a unit of polymict conglomerate of feldspar basalt (or basic andesite) and andesite, with coral and calcarenite pebbles to boulders. Pyroxene andesite, weathering black, occurs among the varied clast types, and other clasts are red, brown, pale green, fawn, etc. There is also a bed of breccia of clasts almost solely hornblende andesite, with however some limestone clasts, most of them obviously coral.

Drola Hydroclastites

This formation consists of various facies of basaltic hydroclastic rocks – breccia (commonly of pitchstone), hyaloclastic tuff and poor to well-formed pillow lava, commonly with coral clasts and thin beds and lenses of limestone. It is well developed on northern Nacula and along the southeastern coasts of Nacula and southern Yaqeta and in islets offshore. Minor occurrences are in northeastern Naviti (and on Nanuyavunivau, Nanuyarara and Qarakali off the east coast), in northwestern Naviti (and on Nanuyanikucuve offshore in the west), on Nanuyalevu and Nanuyasausau to the south, on Tavewa, possibly at three places on Yasawa, and on Yanuya in the Mamanuca Group. The Navotua Andesite of Nacula occurs almost wholly within this facies-defined formation, but takes precedence in rank, i.e. the Drola Hydroclastites as shown on the map is intended to include no rocks consisting wholly or predominantly of pyroxene andesite. Relatively thick sequences of sandstone are shown separately on the map. Hydroclastic rocks also occur in the Nautanivono Andesite but are excluded from this formation because of composition.

Figure 19. Hydroclastic breccia between Naicuacua and Nanuyamagutu Points, northern Naviti; the hammer is 35 cm long.

The northeastern tip of Balaiyanuya (east of central Nacula) shows a type of structure that can be expected where lava meets the sea and explosive activity sends detritus in all directions. Well-bedded fine to coarse sandstone dips at 30^o to the northeast; lapping onto it is a sequence of cobbly pebble breccia dipping south.

The breccia commonly has an unusual colour scheme, typified by that of an outcrop just south of Namoka Creek in southwestern Yaqeta. The chilled margins, now devitrified, are pale yellow-brown grading to pale brown and brown, and the centres of larger clasts are brown to greenish grey. The matrix is commonly green and ranges down to grit grade, with many feldspar crystals, and similar sandstone also occurs in lenses; another common matrix is chlorite plus natrolite and “pseudocalcite”, a mineral somewhat like calcite in crystal form (probably another zeolite).

Fossils, other than coral clasts and those in the limestone, are sparse in the hydroclastic rocks. Molluscs occur in places, though, notably opposite Koroniqalau on the south coast of Nacula, where many individuals of a single gastropod species were found, accompanied by a single *Cypraea*, and along the north shore of Drola Bay near its eastern end, where rare molluscs occur in sandstone with coral clasts (including a *Fungia*) and isolated pillows and pillow fragments. Isolated gastropods occur elsewhere, for instance north of Naisisili.

Most of the limestone lenses in the Yasawa Volcanic Group are assigned to the Vatuya Limestone and are described under that heading.

Dykes intruding the rocks of this formation commonly show features suggesting a very shallow level of intrusion, and in some cases appear to have been the feeders for the surrounding rocks. A dyke on the north side of the Korodole headland (W Nacula) has multiple chilled margins on the west side, which have spilt off and have fine-grained pebble breccia in between; the inner edges are straight but the outer edges of some are very irregular. Another dyke close by appears in the bench but not in the cliff. The point west of Tadrai Point in southern Nacula has a 4-m dyke, the sides of which have re-entrants and bulbous buds.

Figure 20. Large coral in basaltic breccia; Drola Hydroclastites, northern Tavewa.

Vatuya Limestone

This formation is named after the point on the east coast of Nacula north of Vagani Bay, and is separated as a formation because it reaches 15 m in thickness there and is a mappable unit both there and elsewhere. It is not correlated with the Verona Formation (Wainimala Group) because of its different stratigraphic position. The presence of *Lepidocyclina* in the limestone at Vatuya Point and near Naisisili on Nacula, and on Tavewa, indicates an age no younger than about 5.2 Ma (the youngest autochthonous occurrence of the genus currently known – Adams et al. 1979).

The limestone units on Nacula and Tavewa are almost without exception within rocks that have various features of hydroclastic rocks as described under Drola Hydroclastites. Most units are 1-2 m thick, and the longest (above the southern shore of Drola Bay, and north of Naisisili) are about 350 m long; some occurrences can be traced laterally for only a few metres or a few tens of metres.

The limestones mostly appear to be very pure, but no analyses are available yet.

On Yasawa the limestone units occur mainly within the Naitataniika Sandstone in the central and northeastern parts of the island. Again, the thickness of individual units is usually in the range 1 to 2 m. However, there is an important lithological difference between the limestones of Nacula and Tavewa and those of Yasawa. Most of those on Nacula and Tavewa contain common to abundant larger foraminifera, whereas no foraminifera have been found in hand specimens of the limestone from Yasawa (other than one smaller benthic foraminifer in one specimen), which is coralliferous (and no doubt also contains calcareous algae). Larger foraminifera have been recorded from Yasawa, but they occur in volcanic grit with limestone fragments within the Cosiga Pillow Lavas east of Tamusua.

Macrofossils found in the limestones on Yasawa are almost solely corals. Coral clasts occur widely in the volcaniclastic rocks of most formations – the Cosiga Pillow Lavas, Bukama Dacite, Nabukeru Breccia and Naitataniika Sandstone. Most are pebbles and cobbles, but a bed of reworked lapillistone north of Cosiga Point includes one block 1 m long and 30 cm thick. In some cases, such as several beds in Manuqila Bay and at Enebuka in the northeast, and at Naivatikidro in the far southwest (Figure 3), they are so common that the rock could be termed coral-volcanic breccia. Coral forms 60-70 per cent of some beds. Despite this high percentage of carbonate in the rock, these beds are not included in the Vatuya Limestone because they have a volcaniclastic matrix; the Vatuya Limestone by definition comprises strata with carbonate matrix. The only macrofossils other than coral that were found on Yasawa and associated islets (other than in the Sawa-i-lau Limestone and Verona Formation of the Wainimala Group) are one oyster at Nasuva Point and one tiny gastropod plus probable pelecypod fragments found at Naivatikidro, where one 5-cm bed consists of almost continuous coral fragments. One definite smaller benthic foraminifer was seen in a calcareous unit at Dalomo, this being the only case of a non-coral fossil recognisable with hand lens, other than planktonic foraminifera in volcanic sandstone.

Navotua Andesite

Pyroxene andesite, commonly pitchy, occurring as breccia and massive bodies (probably flows), composes this formation. It occurs in northern Nacula and on the adjacent islets Buabua, Naikavu and Yadravaqele (also on Yadravavatu?). The lack of pyroxene andesite close by to the south, and in southern Yasawa to the north, suggests that the massive andesite might be near the centre of eruption. The andesite of Viwa (adjoining Yaqeta on its east) is correlated with this formation.

The massive andesite occurs at Veto Point at Navotua, and forms much of Buabua islet nearby and Yadravaqele to the east. The breccia occurs to the west, stratigraphically not far above the Cosiga Pillow Lavas, and on the northern part of the tableland in the southwestern part of northern Nacula. It is fairly consistently cobble breccia with pitchy clasts having fairly common plagioclase phenocrysts, in some cases with pyroxene phenocrysts visible in hand specimen. Clasts commonly show flow layering.

The matrix is usually brown, and sandy with crystals. The matrix has masses of chlorite+zeolite on the north side of Narororo Point. Quartz and zeolite occur in the matrix elsewhere. Veins and uncommon irregular masses of milky quartz are widespread, one mass at Narororo Point being 10 cm long and 5 cm wide. The veins are usually no more than 10 cm wide, but one seen swells to 15 cm in one place. Some clasts in breccia west of Mataniqara have crystal-cumulate inclusions up to 1 cm long. The eastern extent of the formation is as yet uncertain, because to the east there is a thick sequence of basaltic pitchstone breccia, which looks quite similar. Much of the andesite breccia appears to have formed in shallow water and the Navotua Andesite thus occurs at least largely within the Drola Hydroclastites. Its age is not known directly but it was assumed to be Late Miocene, about 6 to 7 Ma. However, dates obtained by J Gascoyne (Taylor et al. 2000) and palaeomagnetic data suggest that it is Early Pliocene.

Nato Basalt

The Nato Basalt (pronounced Nah'***toh*** with the stress on the second syllable) comprises subaerial basaltic rocks ranging from flows through breccia and lapillistone to tuff. These rocks occur on Yaqeta, the two larger Nanuya islands and Nacula, and certain small associated islets. There are also two occurrences on Naviti. The rocks of Matacawalevu are somewhat puzzling in that they do not show the common oxidation seen on Yaqeta and Nacula, and in the two larger Nanuya islands. However, all are assumed to be subaerial. They are described separately.

The type section is in northern Yaqeta, and consists of an alternation of flows, 1-4 m thick, usually with brecciated top and sometimes base, with red breccia and some tuff. Some units just below flows are red, as are also occasional zones in breccia. Some flows have layering which commonly produces platy joints. The breccia is usually of cobbles with pebbles and blocks, some of the larger ones reasonably rounded; some breccia is multicoloured and polymict but most is monomict. Minor patches of breccia have much zeolite matrix. The basalt is mainly plagioclase rich here, with common zeolite amygdales, up to (rarely) 3 cm, but some types are aphyric. It is usually pale to medium grey, commonly with a purplish tinge. Complex masses of lava occur in the breccia, which is possibly ‘a‘a with massive unbrecciated parts. Flow layering is contorted in these masses. Natolevu is mainly breccia plus massive plagioclase-rich basalt, purple grey, with a joint system. Oxidation of breccia matrix to bright red is very common.

Matacawalevu is an enigma. The two eastern protrusions are relatively normal basalt flows and breccia with some tuff, the southern protrusion also having gabbro sills up to perhaps about 70 m thick. The basalt of the flows is usually dark to medium blue-grey to green-grey, of both plagioclase-rich and aphyric (including trachytic) types. None of the breccia has been oxidised and in fact on the whole of the island there is almost no red rock at all.

These eastern protrusions are separated from the main north-south mass of the island by areas of alteration or sand flats. West of the altered areas the rocks are propylitised, with chlorite and calcite, also in places epidote and pyrite. Much of the breccia that is surely basaltic now has the colours commonly shown by dacite breccia of the Monu Dacite – pale green, purplish, lilac. The fine-grained, flow-laminated aphyric basalt in particular has been affected. Many dykes resemble dacite in being fine grained and aphyric or with sparse feldspar phenocrysts; they are commonly green or green-grey, many of them with purplish margins 5-10 cm wide, or purple-lilac or red. They have good flow lamination and in some dykes there are thin razorblade stringers of presumed quartz, a few millimetres long, along the layering (also noted in clasts in some breccia). However, these dykes are surely basalt, being relatively thin, many of them half a metre wide or less (one is only 20 cm), much thinner than most dacite dykes seen elsewhere. Only one definite dacite dyke was seen, 0.6 km south of Matacawalevu village; it is 0.4 m wide and consists wholly of breccia without any unbrecciated margin.

The stage at which propylitisation took place is uncertain. Clasts consisting wholly of epidote, or of calcite and epidote, occur in breccia in several places, for instance on the north coast of Koroiko and on the central west coast of Matacawalevu north of Mago beach. Epidote also occurs east of Korosavuka Point. Clots of epidote occur in the central zone of one dyke and in occasional lenses near the margin. The quartz-bearing microgabbro and gabbro of the north coast contains both epidote and pyrite. However, eruption of the lava that built the present easterly protrusions of the island apparently took place before the propylitisation, because many of the dykes intruding the sequence of relatively fresh basalt are propylitised. Epidote occurs in one dyke on Nanuyalevu.

The altered areas show leached rock with ferruginous and manganiferous deposits in cracks and joints, or are wholly altered and weathered to clay in which the relict structure of breccia is commonly obvious in fresh exposures. In addition to the large altered area west of Matacawalevu village, there are minor exposures south of Vuaki. Taking them in combination, including a small outcrop on the “reef” flat west of Navava, it seems likely that much of the sand flat south of Vuaki lies on altered rocks.

Surprisingly, pyrite is not visible in the altered areas; neither Kavalieris (1984) nor Lum (1984), who studied the main area in detail, saw any, nor did the present author see any while passing over the main area or inspecting the other areas found. It occurs only in propylitised dykes and other intrusions, or in occasional rocks elsewhere, for instance in relatively fresh basalt west of Matacawalevu village (between the main altered area and Nasomo Bay) and in breccia on Likuliku beach north of the main altered area.

Tokalau Limestone Group

Yaqeta Limestone

The Yaqeta Limestone comprises a mass of limestone overlying the subaerial basaltic rocks of southwestern Yaqeta. The length of time between formation of the subaerial sequence and of the limestone is not known but the formation is included in the Tokalau Limestone Group because it appears to be rather younger than the underlying basalt.

The limestone has been broken into two main parts, appearing to be a single knife-like ridge, by solution and weathering along joints and cracks. It is white to off-white, massive calcarenite, vaguely bedded in places. There are echinoid spines and rare foraminifera in it, and lumps of coral and/or algae up to several centimetres across.

Although no outcrop was found, volcanic sandstone with calcareous matrix might be associated with the limestone, presumably underlying it and concealed by scree and/or soil. On the south side of the western talus mass, there are some floaters consisting of angular volcanic sand in calcareous matrix. Floaters of similar sandstone occur on the slope west of the limestone mass; some of the particles in it might be fragments of molluscs.

The limestone body sheds scree in two main directions, north and west, producing two rounded capes on the coast. Among the blocks in this scree was seen one 3-4 m across that appears to be secondarily cemented limestone, consisting of blocks 1-2 m across, showing the vague bedding, in a rubbly matrix. This process might have occurred relatively recently, within the limestone mass. Limestone blocks also occur southwest of the outcrops, along the coast northwest of Taunovo beach.

The limestone has been assigned to the Tokalau Limestone Group rather than the Yasawa Volcanic Group because of the implied tectonism that occurred between eruption of the Nato basalt and deposition of the limestone.

Ucuna Limestone

The Viwa islands are formed almost wholly of reef limestone (and probably associated facies), with very minor amounts of sand and beach-rock. Level surfaces within the group, at 2-3 m, 6-7 m and 15-19 m AMSL, suggest at least three stages of emergence. Beach-rock and reef in southeastern Viwa, about 1.5 m above their modern counterparts, indicate a fourth negative movement of the strand line; they probably correlate with similar features and emerged notches at about the same elevation on Viti Levu, Vanua Levu and islands of the Lau Group, and this emergence seems undeniably eustatic in origin. The limestone of the islands contains abundant coral heads, mostly in position of growth, and coral detritus, also algal masses, mollusc shells, echinoid spines and foraminifera, and is typical emerged coral-algal reef. It is assigned to the Ucuna Limestone and is probably wholly Pleistocene in age; two coral samples from one reef, which reaches 7 m AMSL, have been dated at about 130 ka (Taylor 1978). The limestone and beach-rock are composed wholly of carbonate, and most of the other constituents are thought to have been derived mainly from sea salts.

The limestone is a series of old coral reefs, now emerged to a maximum elevation of about 19 m AMSL. It is pale to medium yellow-brown in colour, weathering to grey or white except along the tidal zone, where it is yellow-brown to greenish. Algal masses are usually off-white when fresh. The most prominent feature of the rock is the large number of coral heads, usually 15 to 40 cm in diameter and height, but occasionally much larger as on Varokavani, where one seen is 2.5 m across and at least 1.5 m high (Fig. 21). Many different species are present, and most are upright, in position of growth. Algal masses are widespread but appear to be much less common; one algal mat seen is 60 cm across. Shells of *Tridacna*, *Trochus*, *Turbo*, *Cypraea* and other molluscs, *Marginopora* tests and echinoid spines also occur throughout, with concentrations here and there. One *Tridacna* valve 65 cm long was found. The matrix of these organic remains is calcareous mud or silt. In fresh limestone there are probably few cavities, but the exposed limestone is cavernous, probably as a result of weathering. Masses of secondary hematite up to about 30 cm across occur in some places in the limestone on Viwa and Varokavani.

Figure 21. Large coral mass in the Ucuna Limestone on Varokavani; 30-cm hammer, partly shadowed, handle almost vertical, 15% of the width of the photo from the left.

Intrusive rocks

Drawaqa Gabbro

The Drawaqa Gabbro comprises sills of gabbro intruding various rocks in the Yasawa Volcanic Group. The thickest sill is that of eastern Naviti, which appears to reach about 200 m. The sill of the type section on Drawaqa is 50-60 m thick. Sills of similar thickness occur in northern Yasawa and on Yawini and Nanuya-i-ra. Formations intruded by gabbro sills are the Cosiga Pillow Lavas and the Bukama Dacite. Relatively thin gabbro sills are common in two sequences of mixed basaltic sandstone and dacite tuff, on the Muanabuwe peninsula in eastern Yasawa and on Buabua to the northeast. Minor occurrences are Caqila (east of Nanuya-i-ra) and the Vaturua islets north of Vawa.

Basaltic sills are also widespread and common in the Yasawa Volcanic Group, but are excluded from the formation by definition. They range in thickness down to less than a metre, for instance at Korokulu Point in western Naviti where there are several sills mostly 5-10 m thick but ranging down to 0.1 m (there are also swarms of thin dykes there, 2 to 10 cm thick). Some sills are of porphyritic microgabbro; if the groundmass is visibly granular and coarser than that of the usual basalt, the sill is considered to belong to the Drawaqa Gabbro.

The gabbro of the sills is usually somewhat porphyritic but some examples are almost wholly holocrystalline with minor, relatively fine-grained material filling interstices. The Naukacuvu sill has scattered clots of zeolite. Some of the sills are well jointed, for instance the Drawaqa sill at Natagavonovono Point is columnar basalt (possibly close to the top of the sill). The margins are chilled and have the texture of basalt, for instance on Nanuya-i-ra where the base is basalt but the rock becomes gabbro within about a metre. The Narara sill also has extensive fine-grained, basaltic parts.

Minerals visible in hand specimen are feldspar and augite and probable hornblende; chlorite is also visible in many samples. Pseudomorphs apparently after olivine occur in some sills, for instance a sill west of Naturuva Point west of the Muanabuwe peninsula in southeastern Yasawa. Amygdales of calcite and/or zeolite are present in many of the sills.

In the north of Yawini a sill near Nawaqalenavara Point is mafic, very different from the felsic types of Vatuliwa (N Yasawa) and Nanuya-i-ra, at least in hand specimen. Some planes have calcite and slickensides. The sill has very strong jointing forming approximately rectilinear columns. Massive, vaguely layered gabbro at Lutuinataga Point occurs in pillow lava; the base of the gabbro is slightly pillowed. A 3-m dyke close by has bulbous projections at its side, almost detached as pillows. There is a large gabbroic mass at the base of the pillow lava in one place.

Aplite veins, almost solely feldspar, are common in some of the sills, commonly parallel to the top or bottom of the sill. They are up to 5 cm thick on Narara where one in a loose boulder increases from ½ cm to 5 cm within ½ m; along one side is a discontinuous layer of augite or hornblende. The Narara sill has much microgabbro. The gabbro on the north side of the larger islet of Vaturua has veins and a mass of fine-grained differentiate and a large ?xenolith of ?microtonalite or crystal cumulate having quartz phenocrysts, and quartz pyramids/prisms in vesicles. There are also uniform veins 1-3 cm wide, and another about 10 cm thick.

Andesite of White Rock

White Rock, east of Kuata, is a rounded knob of hornblende andesite showing flow layering and columnar jointing. The rock is medium brown, very fine grained, with feldspar and hornblende phenocrysts (up to 4 mm and 3 mm respectively), roughly aligned. Some of the largest feldspars are altered. Rare biotite is visible. The layering is shown by colour variation in the groundmass.

Petrographically it is of interest. The hornblende is euhedral, strongly coloured, and zoned, with up to three cycles of pale (pleochroic to medium olive-brown) grading to dark (pleochroic to olive-black); the rim is dark in all cases; zone boundaries are mostly gradational though some transitions from dark to light are sharp. There has been slight digestion of some rims but there is usually no magnetite resorption rim, though some crystals have some granular magnetite. Many crystals have altered material at the centre, apparently a nucleus, now altered, on which the crystal grew; one nucleus is a tiny crystal of augite. The plagioclase is cyclically zoned with up to 3½ cycles. Some quartz occurs in the groundmass, with magnetite and rare apatite. Rare biotite was seen in hand specimen. The plagioclase has composition around An_{50} – in one crystal three measurements gave An_{47}, An_{55} and An_{47}. The rock is actually a trachydacite.

STRUCTURE

The Yasawa-Malolo island chain consists of two structural provinces, one comprising all islands from Yasawa (with the two Nanuya islets to the north) to the main part of the Mamanuca Group (and Vomo and Vomo Lailai appear to also belong here), and the other the Malolo Group and eastern Mamanuca islands. There is some puzzling overlap in the structure of the two.

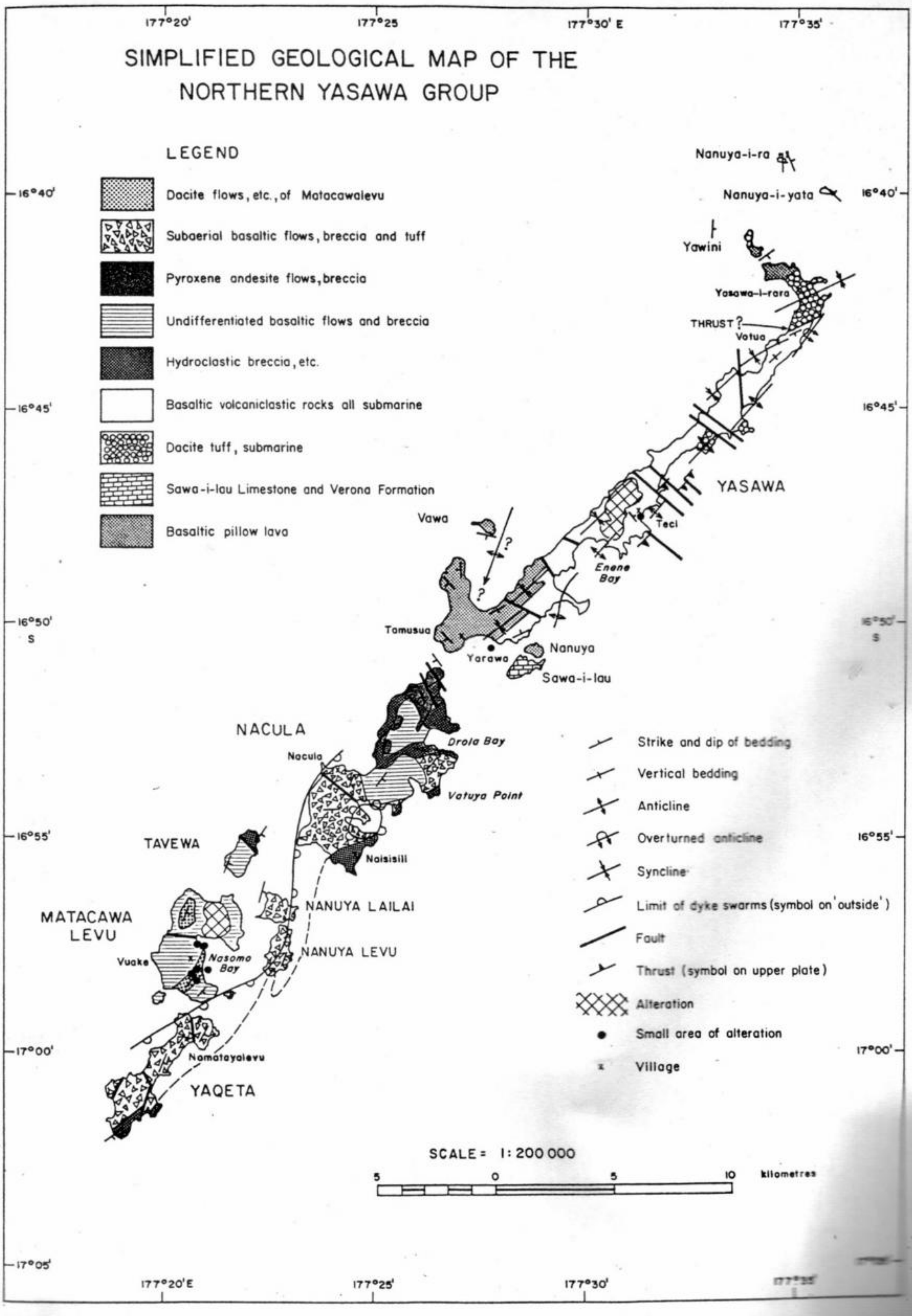
The chain of islands in the Narokorokoyawa and Yasawa Groups is basically a monocline dipping moderately to gently towards Viti Levu, with isolated dacitic volcanic centres from Windy Rock off Waya southwards to the Mamanuca Group. The basaltic rocks of Tokoriki in the Mamanuca Group, the Narokorokoyawa Group, Wayasewa and eastern Waya (Dakadaka Basalt, Wainimala Group) reveal at least part of the rift zone from which the Dakadaka basaltic rocks were erupted. The basalt sequences on the islands are intruded by abundant dykes, some of them known to be contemporaneous because of offshoots which form the matrix of pillows in lava units. The strikes of the dykes cluster around a direction essentially parallel to the chain of islands (and of the strikes of the rocks). Tokoriki has only a few contemporary basalt dykes but they trend northerly and show that the island belongs structurally to the islands adjoining to the north.

The younger basaltic rocks, of the Yasawa Volcanic Group, also appear to be the product of fissure eruptions. However, they were apparently erupted from a zone slightly west of the Dakadaka fissure zone because although dykes are common, they are rarely so common or so parallel as to indicate a fissure zone. Two exposed fissure zones are however apparent, the main one in northwestern Yaqeta, Matacawalevu, the Nanuya islands, Tavewa and westernmost Nacula (with Yaroma), and the other in a small area in southeastern Nacula (Fig. 22 below, from Rodda 1986). This latter zone suggests a concentration of volcanic activity in southeastern Nacula, and the abundant dykes of many different strikes in Matacawalevu suggest that there was another main volcanic centre in the vicinity. The fissure zones occur in subaerial volcanics, which extend about 2-3 km southeast of the margin of the main fissure and are bordered by the zone of hydroclastic rocks.

Vomo and Vomo Lailai appear to belong to the main chain of the Yasawa Group in that the strikes of the rocks and of the dykes are slightly east of north, similar to those of the rocks and dykes of the main chain to the west.

There are two major variations in this monocline. One is a simple fold pair that affects only Waya, the other is a complex of thrusts, folds and faults affecting only Yasawa and some adjoining islets and isolated rocks. Additionally, there is a puzzling structure on Matacawalevu.

On Waya, both eastern and western parts of the island are monoclines with about equal attitudes, with a tight fold pair, probably faulted to some extent, producing a vertical and overturned sequence about 1000 m thick in the north, running roughly centrally through the island from north to south. This is best seen at Koromasoli Point and along the eastern shore of Nalauwaki Bay. At Koromasoli Point microfaulting is very common, with low dip to the east, throw usually 3-5 cm but with faults every 8-15 cm; the top moved to the east in east-west faces. A major fault is shown on the map, in effect almost completely separating the rocks of the Wainimala Group from those of the Yasawa Volcanic Group. The fault might not, however, be quite as important as is implied; the anticline and syncline might instead approach each other to almost cancel in the south, where the vertical limb hardly exists. Nevertheless, both M. Williams (1969) and the present author considered that there is a fault at Nukubavatu in the northeast, and a fault is visible in Olo Creek about 1200 m from the southern shore, striking about 013TV (with slickensides in the east face, dipping 45-60^{o} to the southwest).



177°20'
177°25
177°30' E
177°35'
SIMPLIFIED GEOLOGICAL MAP OF THE
NORTHERN YASAWA GROUP
LEGEND
Dacite flows, etc., of Matacawalevu
Subaerial basaltic flows, breccia and tuff
Pyroxene andesite flows, breccia
Undifferentiated basaltic flows and breccia
Hydroclastic breccia, etc.
Basaltic volcaniclastic rocks all submarine
Dacite tuff, submarine
Sawa-i-lau Limestone and Verona Formation
Basaltic pillow lava
Nanuya-i-ra
Nanuya-i-yata
16°40'
Yawini
Yasawa-i-rara
THRUST?
Votua
16°45'
YASAWA
Teci
Vawa
Enene Bay
16°50' S
Tamusua
Yaravva
Nanuya
Sawa-i-lau
NACULA
Nacula
Drola Bay
Vatuya Point
16°55'
TAVEWA
Naisisili
NANUYA LAILAI
MATACAWA LEVU
Vuake
Nasomo Bay
NANUYA LEVU
17°00'
Namatayalevu
YAQETA
Strike and dip of bedding
Vertical bedding
Anticline
Overturned anticline
Syncline
Limit of dyke swarms (symbol on 'outside')
Fault
Thrust (symbol on upper plate)
Alteration
Small area of alteration
Village
SCALE = 1:200 000
5
0
5
10
kilometres
17°05'
177°20'E
177°25'
177°30'
177°35'

Ages of the rocks

Wainimala Group

Dakadaka Basalt, suggested to be in the range Late Eocene to Late Oligocene by poorly preserved nannoplankton.

Nabu Formation on Eori, CP19a to CN1a, Late Oligocene to very earliest Miocene (P. Quinterno, *pers. comm*., 1986), i.e. in the range 30.3 Ma to 23.4 Ma (Harland et al. 1990).

Yasawa Volcanic Group

Bukama Dacite on Naukacuvu (south of Naviti): a limited planktonic fauna giving only a broad age range, Middle Miocene to Early Pliocene (N.11-N.18) – D. Belford, *pers. comm*., 1984.

Cosiga Pillow Lavas close to Vakatawalevu (of eastern Naviti – younger than N.18 or the upper part of N.17. (R. Todd, *pers. comm*., 1973).

Nalauwaki Andesite – Late Miocene to Early Pliocene (nannoplankton).

Tokalau Limestone Group

Ucuna Limestone – reef 6-8 m AMSL, about 130 ka (Taylor, F.W., 1978).

Radiometric dates show a range from 8.0 Ma to 5 Ma, with some younger dates down to 4.2 Ma. Some of the younger dates are surely too young because *Lepidocyclina* occurs in the Vatuya Limestone above the dated rocks, or along strike, and this is not known from Pliocene strata. However, Taylor et al. (2000) stated that the Early Pliocene date for the Navotua Andesite is confirmed by their palaeomagnetic data. The andesite of White Rock, which might be correlatable with the Nalauwaki Andesite, was dated at 8.3 ±1.5 Ma (Snelling & Chan 1971).

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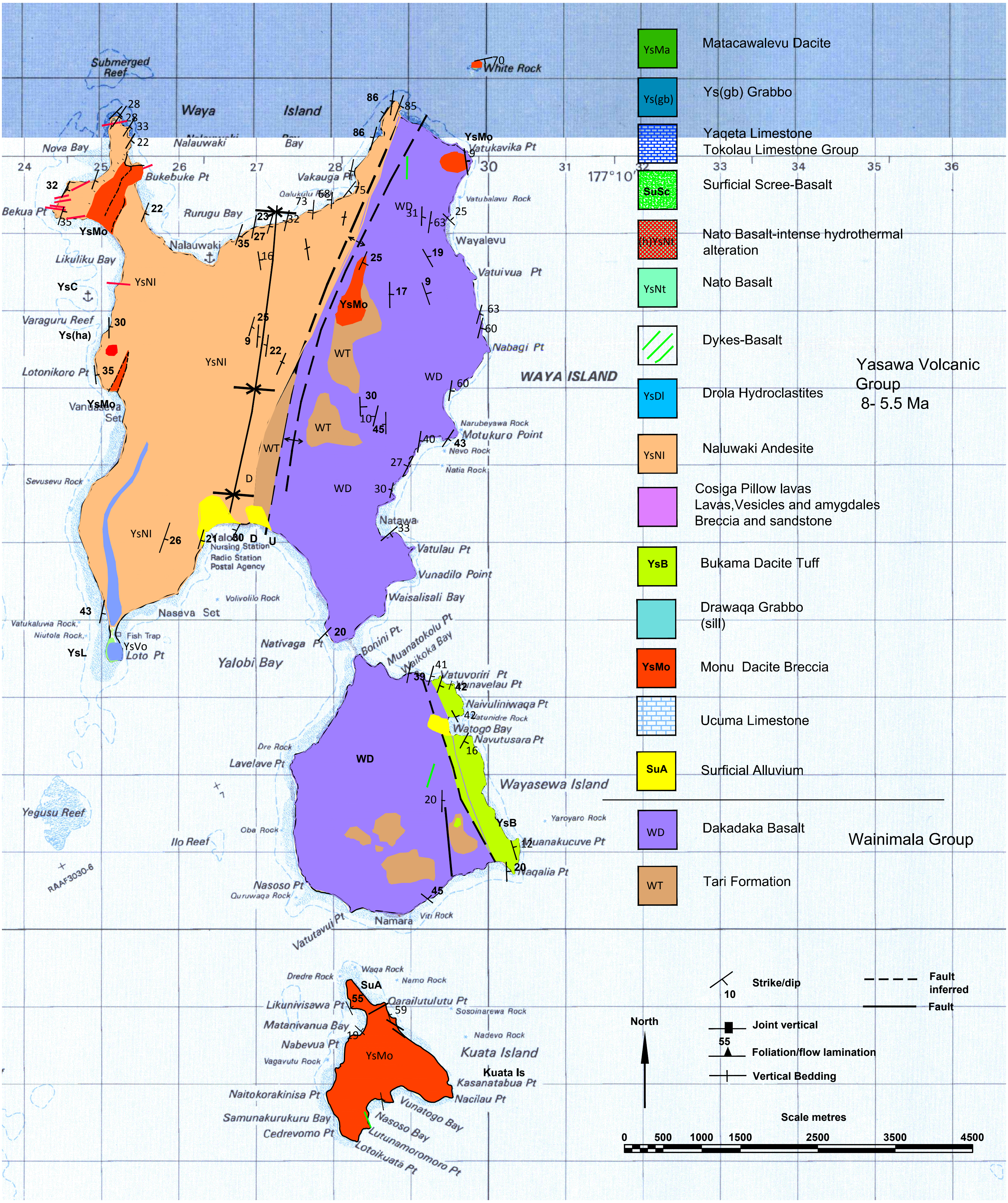
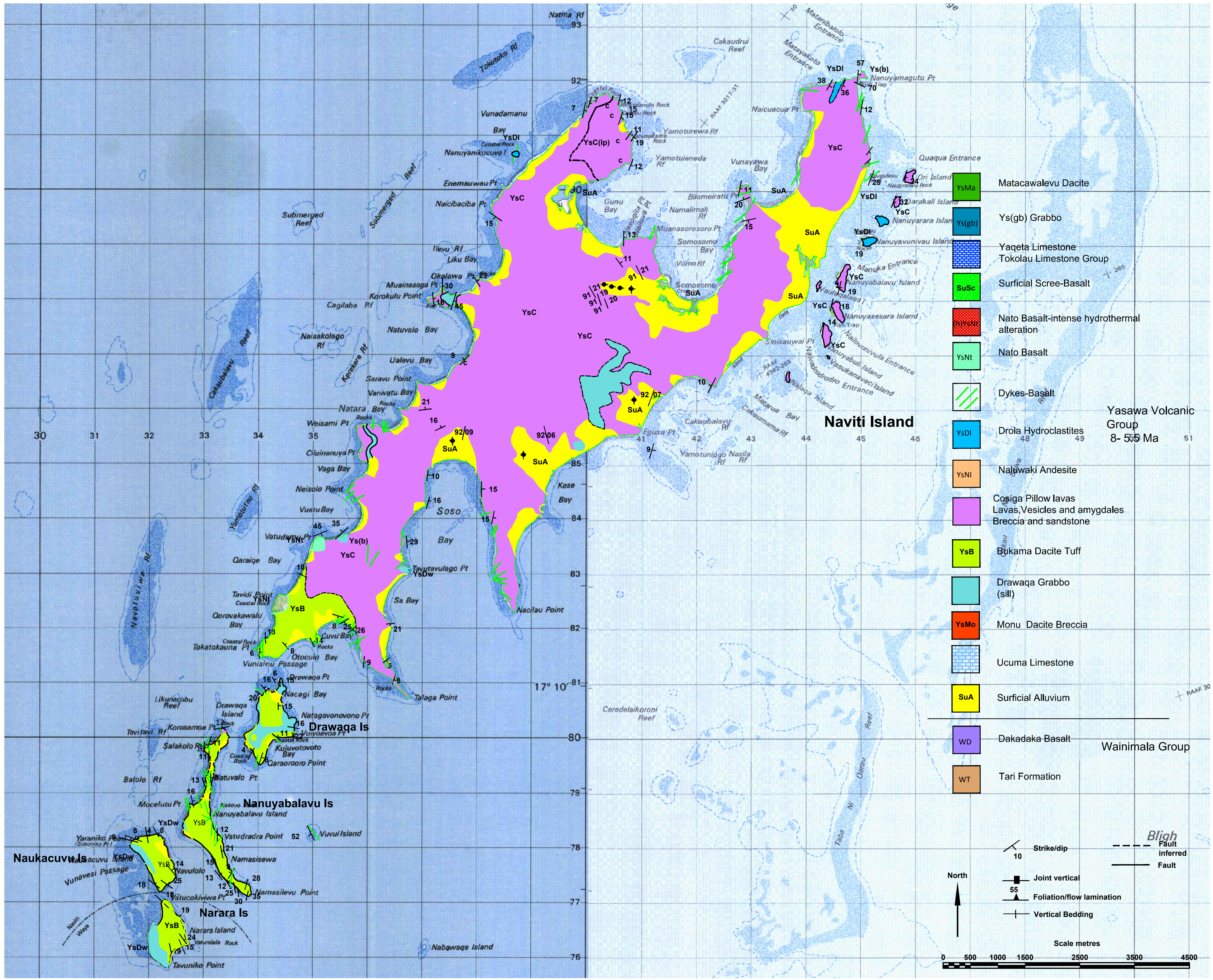
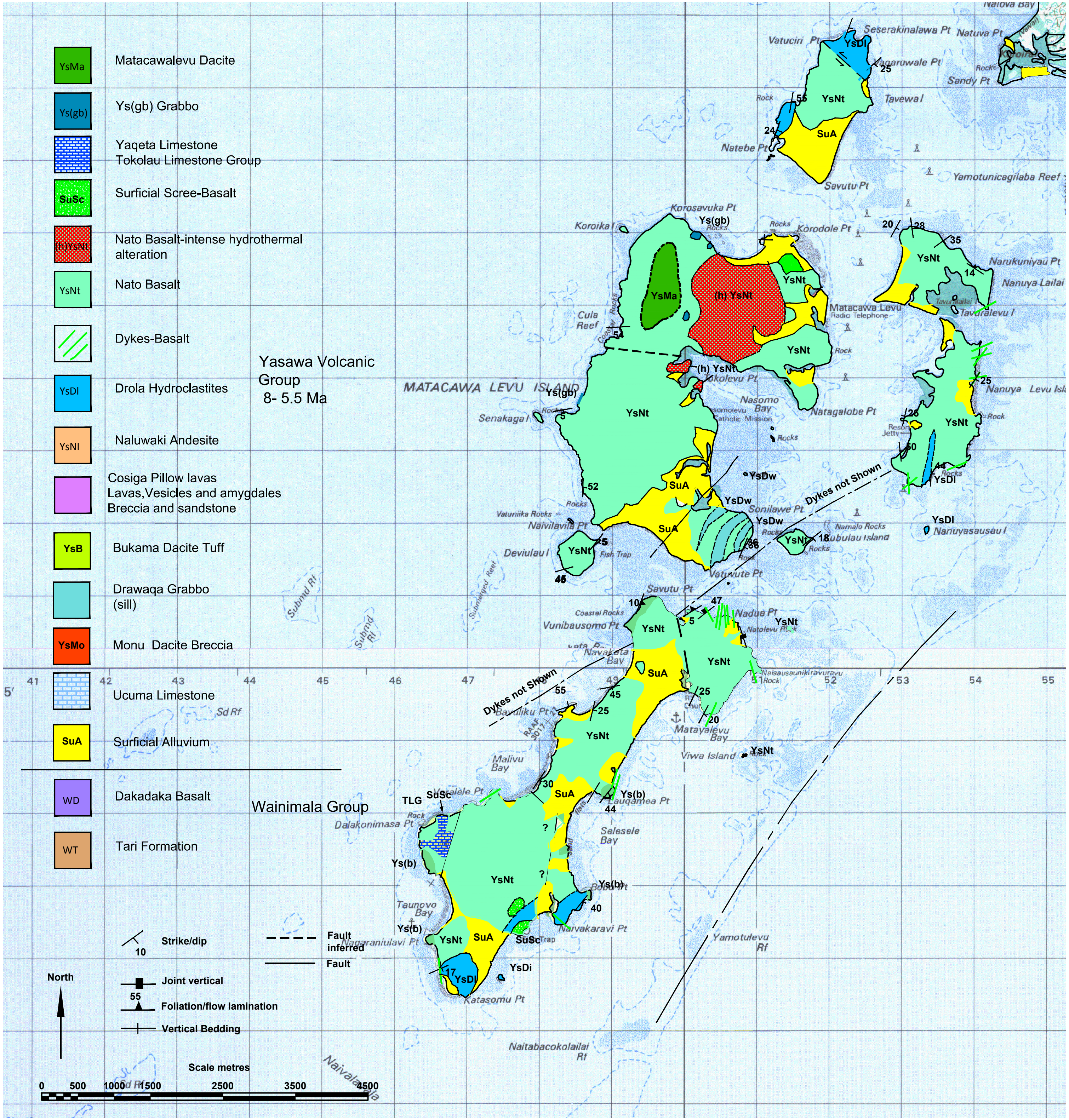
The Geology of Yasawa Islands by Peter Rodda has never been published. These maps are a work in progress and the best we can do for now to prepare them for the STAR 2016 field trip.





Naviti Island
Drawaqa Is
Nanuyabalavu Is
Naukacuvu Is
Narara Is
Matacawalevu Dacite
Ys(gb) Grabbo
Yaqeta Limestone
Tokolau Limestone Group
Surficial Scree-Basalt
Nato Basalt-intense hydrothermal alteration
Nato Basalt
Dykes-Basalt
Drola Hydroclastites
Naluwaki Andesite
Cosiga Pillow lavas
Lavas,Vesicles and amygdales
Breccia and sandstone
Bukama Dacite Tuff
Drawaqa Grabbo
(sill)
Monu Dacite Breccia
Ucuma Limestone
Surficial Alluvium
Yasawa Volcanic Group
8- 5.5 Ma
Dakadaka Basalt
Tari Formation
Wainimala Group
Strike/dip
Joint vertical
Foliation/flow lamination
Vertical Bedding
Fault inferred
Fault
North
Scale metres
0 500 1000 1500 2500 3500 4500



YsMa Matacawalevu Dacite
Ys(gb) Ys(gb) Grabbo
Yaqeta Limestone
Tokolau Limestone Group
SuSc Surficial Scree-Basalt
(h)YsNt Nato Basalt-intense hydrothermal alteration
YsNt Nato Basalt
Dykes-Basalt
YsDl Drola Hydroclastites
YsNl Naluwaki Andesite
Cosiga Pillow lavas
Lavas,Vesicles and amygdales
Breccia and sandstone
YsB Bukama Dacite Tuff
Drawaqa Grabbo
(sill)
YsMo Monu Dacite Breccia
Ucuma Limestone
SuA Surficial Alluvium
Yasawa Volcanic
Group
8- 5.5 Ma
WD Dakadaka Basalt
WT Tari Formation
Wainimala Group
Strike/dip
Fault
inferred
Fault
North
Joint vertical
Foliation/flow lamination
Vertical Bedding
Scale metres
0 500 1000 1500 2500 3500 4500
MATACAWA LEVU ISLAND
Dykes not Shown
Dykes not Shown
Vatuciri Pt
Seserakinalawa Pt
Natuva Pt
Sandy Pt
Tavewa I
Natebe Pt
Savutu Pt
Yamotunicagilaba Reef
Korosavuka Pt
Koroika I
Korodole Pt
Narukuniyau Pt
Nanuya Lailai
Tavuralevu I
Matacawa Levu
Radio Telephone
Cula
Reef
Nasomo
Bay
Natagalobe Pt
Nanuya Levu Isl
Senakaga I
Sonilawe Pt
Naviti Islands
Nanuyasauseu I
Naivilavila Pt
Deviulau I
Fish Trap
Vatuvute Pt
Savutu Pt
Nadua Pt
Vunibausomo Pt
Coastal Rocks
Navakata
Bay
Matayalevu
Bay
Viwa Island
Bavuliku Pt
Malivu
Bay
Vavaleka Pt
Dalakonimasa Pt
Nauqamea Pt
Selesele
Bay
Taunovo
Bay
Nagaraniulavi Pt
Narvakaravi Pt
Katasomu Pt
Yamotulevu
Rf
Naitabacokolailai
Rf
Sd Rf
Submd Rf