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– ARTICLE –

Petrography of Sand Tempers in Lapita Potsherds from the Rove Peninsula, Southwest Viti Levu, Fiji

William R. Dickinson[1] & Patrick D. Nunn[2]

ABSTRACT

Seven Lapita sites on the Rove Peninsula of Viti Levu in Fiji or on islets close offshore include the earliest known Lapita site (Bourewa) on Viti Levu. Petrographic study of 53 Rove sherds shows that 95 per cent contain closely related hybrid temper sands (mixed terrigenous and calcareous grains) collected locally from the shores of the ancestral Tuva River estuary and adjacent Vusama paleoisland. Terrigenous detritus was derived from the Wainimala orogen that forms the bedrock of southwest Viti Levu and is exposed throughout the drainage basin of the Tuva River. Skeletal and pelletal (micritic) calcareous detritus was derived from the broad offshore reef fringing the Rove Peninsula. In most Rove sherds, calcareous temper grains have been largely or entirely removed by dissolution to leave vacuoles of sand size and shape that are visible megascopically as tiny pits on sherd surfaces. Tempers of indigenous Rove wares did not vary substantially from site to site on the peninsula or over time during its Lapita occupation. Three sherds containing non-local volcanic sand as temper reflect ceramic transfer of exotic wares during later phases of Rove prehistory from Lapita settlements elsewhere in Fiji, probably on Kadavu and the north coast of Viti Levu.

Keywords: Bourewa, Fiji, Lapita, Rove Peninsula, Viti Levu

INTRODUCTION

Migrants who made dentate-stamped Lapita pottery (Figure 1) were the first people to reach multiple island groups southeast of the Bismarck Archipelago near New Guinea by voyaging ~4000 km from their Bismarck homeland to the Lapita fringe in Tonga and Samoa at a mean rate of ~10 km/yr (Dickinson 2006). The Bourewa Lapita site (Nunn *et al.* 2004) on the Rove Peninsula of southwest Viti Levu (Figure 2), the largest island in Fiji, is of intrinsic interest because its deepest cultural horizons record the earliest known human presence on Viti Levu if not in Fiji as a whole (Figure 3). Satellite Lapita communities were established over time both north and south of the central pioneer settlement at Bourewa itself. Evidence for Lapita occupation of the Rove Peninsula includes at least seven localities spread for ~5 km along the Viti Levu coastline inshore from a prominent fringing reef thought to have provided the marine resources needed for sustenance by Lapita settlers (Nunn *et al.* 2004, Clark & Anderson 2009b).

Post-mid-Holocene drawdown in regional Pacific hydro-isostatic sea level has significantly altered the geography of the area surrounding the modern Rove Peninsula since site occupation (Figure 4). At the time of Lapita occupation (Figure 4B), all the sites were positioned on the seaward fringes of small islets separated from the Viti Levu mainland by a broad estuary at the mouth of the Tuva River (Nunn 2005). The Qoqo Lapita site on a small islet surrounded by mangrove today (Figure 4A) is interpreted as a stilt village built over coastal waters (Figure 4B). The estuary and associated coastal embayments have been infilled with sediment during late Holocene drawdown in sea level, and the entire Lapita site complex with the exception of Qogo Island has been incorporated into the Rove Peninsula.

A petrographic study of potsherds collected from the surface and in excavations on the Rove Peninsula was undertaken to understand better the derivation of temper sands used by Lapita potters living in the area. We refer jointly to the subset of sherds examined in thin section as Rove sherds, but 70 per cent derive from excavations at Bourewa. A variety of coastal sands were apparently collected at unspecified localities near the archaeological sites, and added manually as sand temper to clay bodies otherwise lacking sandy impurities. The textural and mineralogical variability of the tempers used for vessel fabrication indicates that the exact nature of temper sand was not of prime importance for the manufacture of Rove earthenware.

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[1] Department of Geosciences, University of Arizona, Tucson, AZ 85721, USA

[2] School of Behavioural, Cognitive, and Social Sciences, University of New England, Armidale, NSW 2351, Australia

Corresponding author: wrdickin@dakotacom.net

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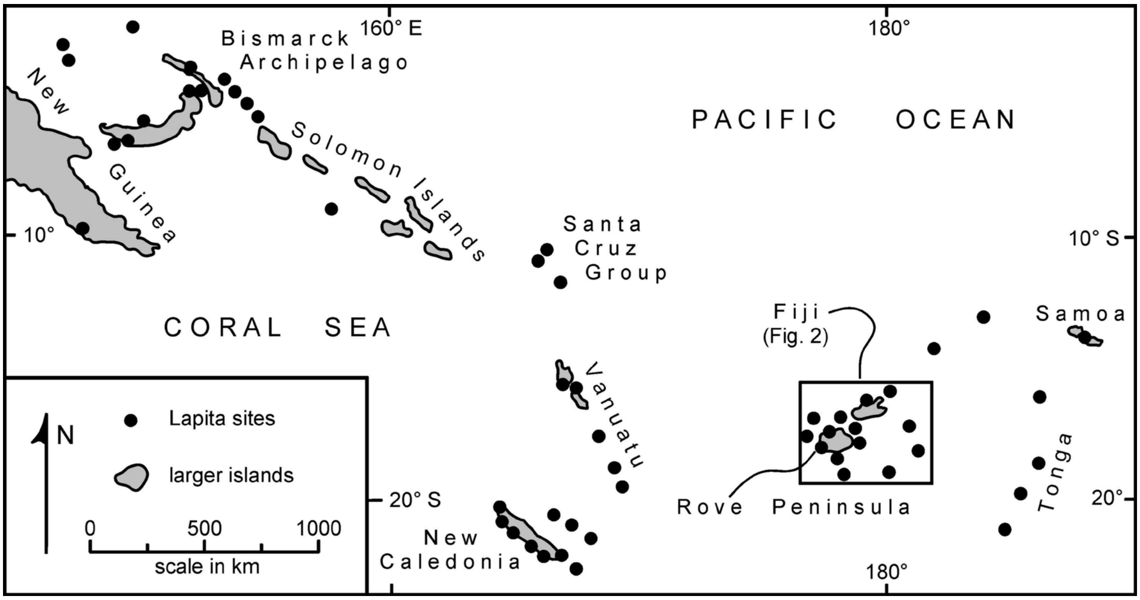

Figure 1. Regional distribution of Lapita sites and site clusters in the southwest Pacific after Anderson *et al.* (2001), Sand (2001), Bedford (2006:157-173), Dickinson (2006), Burley (2010), Bedford *et al.* (2011), McNiven *et al.* (2011), Sand *et al.* (2011), and Figure 2.

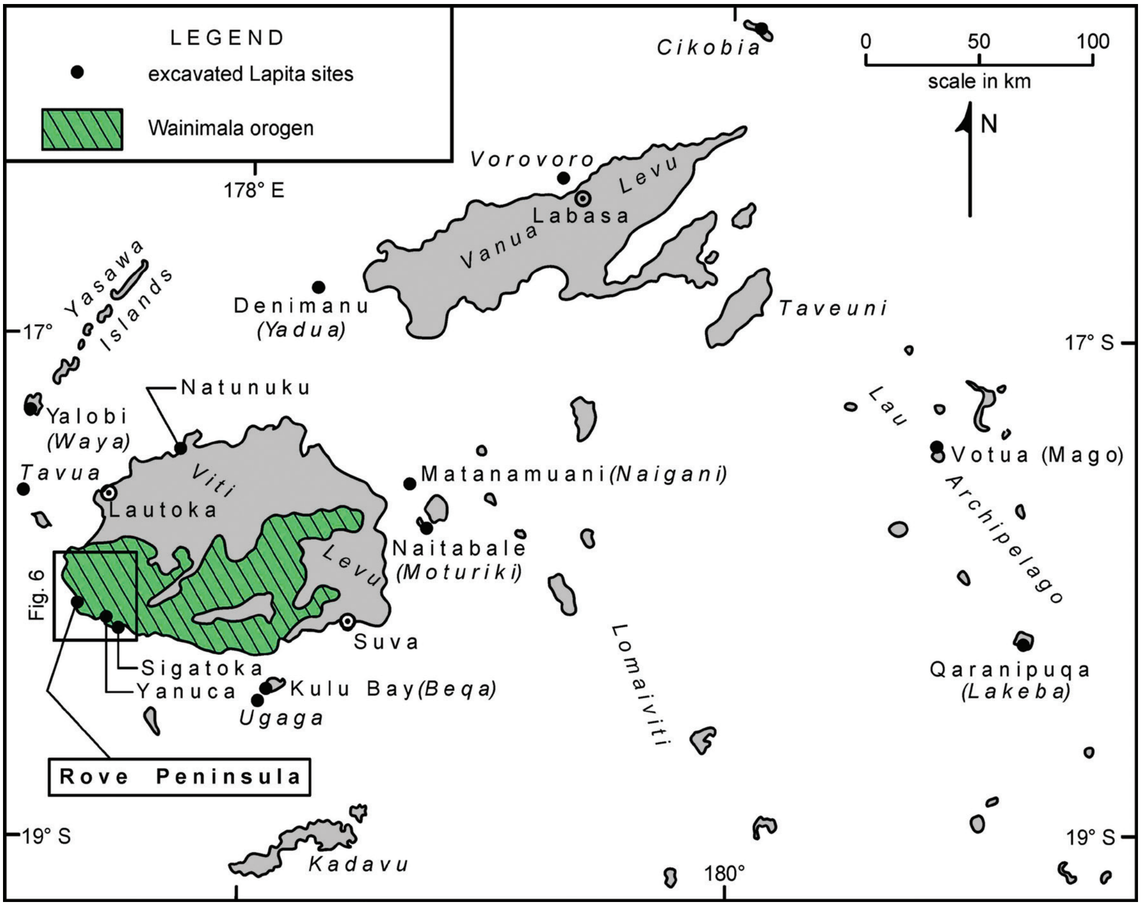

Figure 2. Locations of Rove Peninsula (lower left) and other excavated Lapita sites in Fiji (see Figure 1 for location and Figure 3 for ages) in relation to the Wainimala orogen (ancestral Vitiaz arc-forearc assemblage) of Viti Levu. Island names in italics. No separate site names for Tavua, Ugaga, Vorovoro, and Yadua islands. Two sites (Nakasaga, Naselala) on Cikobia.

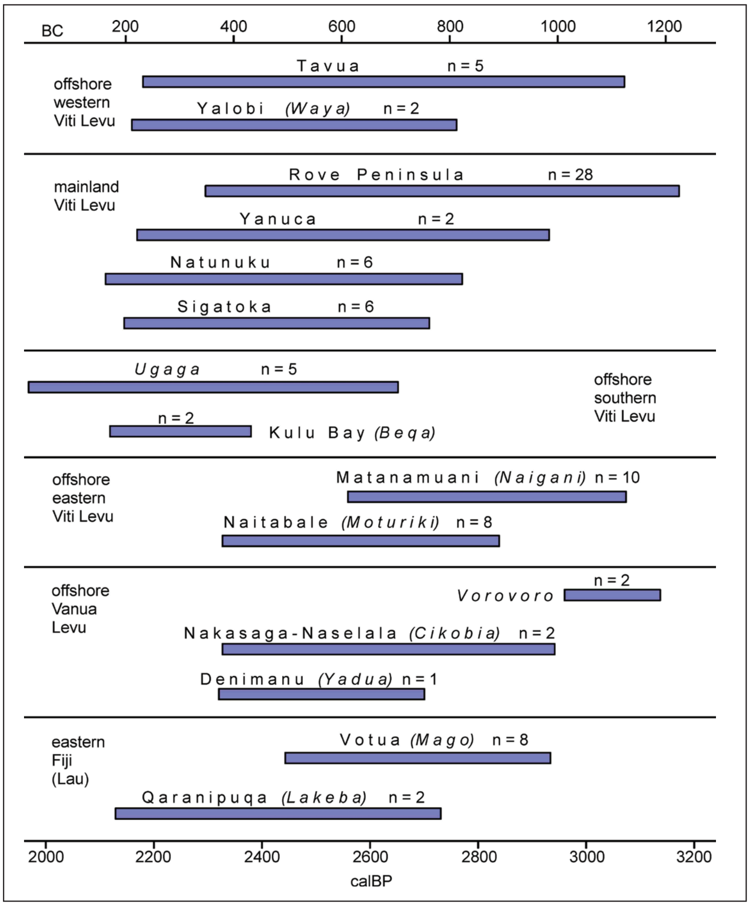

Figure 3. Age ranges of Bourewa and other Rove Peninsula sites compared to other excavated Lapita sites in Fiji (see Figure 2 for locations; n=number of radiocarbon ages used for control). Ranges of calibrated radiocarbon ages (cal yr BP at 2σ) for charcoal and shell (bone ages excluded) from Sand & Valentin (1998), Burley & Dickinson (2004), Nunn *et al.* (2004, 2005, 2007), Clark & Anderson (2009a), Cochrane *et al.* (2011), Irwin *et al.* (2011), and Burley (2012). Isolated outlier dates and dates with uncertainties (±) greater than 75 conventional radiocarbon years omitted.

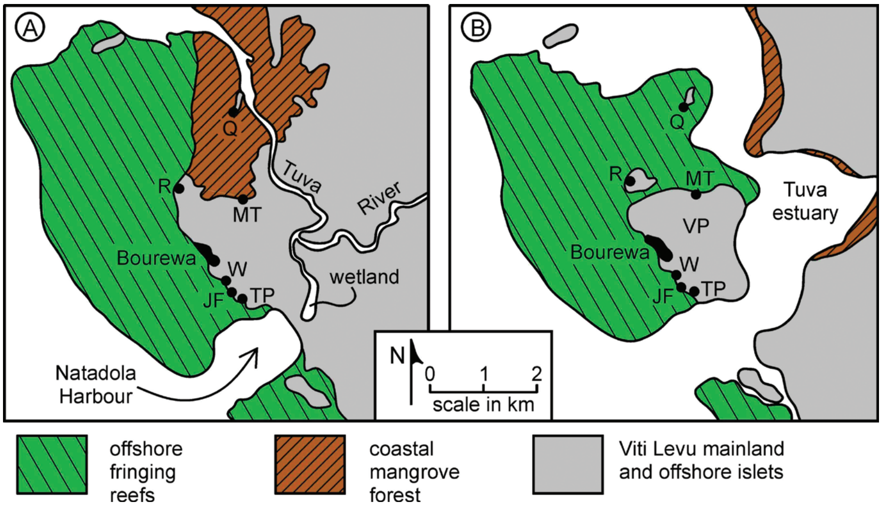

Figure 4. Modern geography (A) and Lapita paleogeography (B) of the Rove Peninsula and environs (see Figures 2 and 6 for location on Viti Levu). Adapted after Nunn (2007) and Nunn & Heorake (2009). Lapita sites subsidiary to Bourewa: JF–Jugendar's Farm, MT–Matelita Tree, Q–Qoqo, R–Rove, TP–Tomato Patch, W–Waikereira. VP denotes Vusama paleoisland (the name is taken from the modern Fijian village of Vusama located within the confines of the paleoisland).

For our petrographic study, we selected nine surface and 44 excavated Rove sherds as representative of the ranges of thickness, coloration, ornamentation, decorative motifs, and megascopic temper appearance observed for the full collection of sherds from Lapita sites on the Rove Peninsula. Special attention was focused on the more intricate and finer dentate decorations thought to be diagnostic of earlier wares somewhat older than younger wares bearing typical iterative Fijian motifs of Eastern Lapita affinity. Full analysis of the typology and decorations of Rove wares is underway but still incomplete, and can now be informed by knowledge of Rove tempers.

Our petrographic appraisal of Rove tempers is at variance with results from a recent study of 15 surface sherds from the vicinity of Bourewa (Rutherford *et al.* 2012), but we are confident that our petrographic information provides a more valid assessment of the varied temper types present in Rove pottery. Three Rove sherds (6 per cent of the total examined in thin section) contain apparently non-local tempers inferred to reflect minor ceramic transfer of exotic wares from other Lapita sites in Fiji. The remaining 94 per cent of the Rove sherds are interpreted as indigenous wares containing locally collected temper sands.

PETROGRAPHIC METHODOLOGY

Sherd thin sections were prepared by standard petrographic techniques, including vacuum impregnation of sherd slices with epoxy, for potsherds (Table 1) collected from excavations at Bourewa and Qoqo, and from the surface at Bourewa, Qoqo, and Tomato Patch (Figure 4). Frequency percentages of grain types in the tempers were determined by crosshair traverse counts (Middleton *et al.* 1985) of 100 grains per thin section, fewer than the 400 grains commonly counted per thin section for temper analysis (Dickinson 2006). The frequency percentages determined by counting fewer grains provide satisfactory counting statistics for the closely related tempers of local origin used for indigenous Rove pottery (Figure 5). Two standard deviations (2σ) of counting error for 100 grains equal one standard deviation (1σ) of counting error for 400 grains (van der Plas & Tobi 1965). The efficiency achieved by counting only ~5000 grains instead of ~20,000 grains in the sherds selected for petrographic study allowed closer attention to the identification of the varied grain types present in the tempers. For our study, qualitative differentiation of grain types is at least as significant as quantitative proportions of grain types. The results of our counting procedure are statistically questionable, however, for grain types present in amounts <5 per cent of net grain aggregates (Figure 5). The Appendix (see supplementary file online at http://www.pacificarchaeology.org/index.php/journal/rt/suppFiles/DickinsonNunn. NOTE: you must be logged in to the *Journal of Pacific Archaeology* website in order to access this file) tabulates the frequency percentages of different grain types in both local and non-local temper sands of Rove sherds, and key supplemental grain parameters or compositional indices defined below.

ROVE HYBRID TEMPERS

All tempers of inferred local origin in Rove sherds are moderately to poorly sorted hybrid aggregates (Zuffa 1979) of fine to medium sand deposited as mixtures of terrigenous grains derived from bedrock of Viti Levu and calcareous grains of skeletal and pelletal origin derived from offshore fringing reefs. The hybrid character of the temper sands is geologically explicable because all potential sites for the collection of coastal temper sands readily accessible either on foot or by paddle canoe from the Rove Lapita sites on offshore paleoislands were well positioned to re-

Table 1. *Provenience (by subsite) of sherds from the Rove Peninsula examined petrographically in thin section. Parentheses denote depths in cm (±5 cm) below the surface. See Nunn (2007) for intrasite pit locations.*

Subsite (Figure 4)	Sherds (thin sections)
Bourewa surface	BS3A, BS3B, ID2
Bourewa A Pits	BO1 (95), BO2 (55), BO3 (75), BO5 (85), BO6 (55), BO7 (85), BO9 (170), BO10 (175), BO11 (205), BO12 (105)
Bourewa C Pits	BO15 (65), BO16 (95)
Bourewa J-L-P Pits	BL4 (75), BP2A (65), BP2B (65), BO17 (65)
Bourea Pits RB2-RB3	BRB2A (5), BRB2B (5), BRB3A (25), BRB3B (65), BRB3C (65)
Bourewa Pit TP5	BTP5A (35), BTP5B (35), BTP5C (35)
Bourewa X Pits	BO19 (105), BO20 (65), BO21 (65), BO22 (75), BO23 (45), BO26 (75), BO28 (85), BO30 (95), BO31 (115), BO32 (125), BO33 (75)
Bourewa Y-Z Pits	BO37 (75), BO 38 (135)
Qoqo surface	QS4A, QS4B, QSJ
Qoqo Pit R2	QR2A (35), QR2B (35), QR2C (85), QR2D (135), QR2E (135), QR2F (135), QR2G (135)
Tomato Patch surface	TOM4, TOM5A, TOM5B

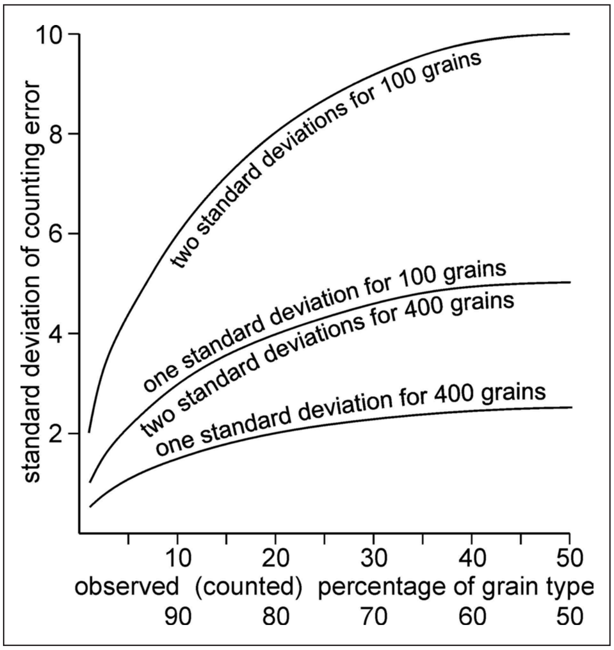

Figure 5. Standard deviations of counting error for counts of 100 and 400 grains. Counting error (van der Plas & Tobi 1965) is given by CE = [p(100–p)/n]½ where p is the observed (counted) percentage of a grain type and n is the number of grains counted.

ceive both terrigenous sand delivered from inland sources to the shores of the Tuva estuary and calcareous sand washed landward into the Tuva estuary from extensive offshore fringing reefs (Figure 4B). In most Rove sherds, the calcareous grains of reef detritus have been largely or entirely removed by post-depositional leaching and dissolution of calcareous grains to leave vacuoles visible as equant voids of sand size and shape in thin section. The vacuoles are revealed megascopically by tiny pits of sand size and shape on sherd surfaces.

Leaching of calcareous grains from potsherds by surficial weathering or the subsurface percolation of vadose waters is a well known phenomenon for many Oceanian temper suites (Dickinson 2006: 21). A salient example is the sherd assemblage from the Katem site on Lelu Island, a small islet off the east coast of Kosrae in Micronesia (Dickinson 1995). Katem sherds contain exclusively calcareous temper sand of reef derivation, but the calcareous grains have been removed from many of the sherds by post-depositional dissolution. Prior to petrographic study, the Katem sherds lacking calcareous temper grains were interpreted as untempered, but their non-calcareous character stems entirely from the removal of calcareous grains. Tell-tale vacuoles and vacuole pits indicative of grain dissolution are prominent in thin sections and on sherd surfaces of the non-calcareous ‘untempered’ sherds.

The characteristic setting of Lapita settlements in the southwest Pacific on surficial coastal sediments implies that most associated potsherds have been exposed to potential dissolution of calcareous temper grains during infiltration of the underlying sediment by vadose subsurface waters percolating downward from the surface. Acquisition of organic acids from decaying vegetal matter littering the surface or buried with sediment in the prevailing humid tropical climate enhanced the ability of ambient waters to dissolve calcite. Appreciation of the hydrochemical environment of ancient Lapita sites underscores the importance of evaluating both the residual and the original distribution of calcareous grains in sherd tempers. Many coastal sands available as potential temper in the vicinity of Lapita sites are hybrid sands composed of mixed terrigenous sand washed down to the coast from island interiors and calcareous sand transported toward the coast from offshore fringing reefs. The survival of calcareous temper grains as a component of sherds collected in modern times depends upon vagaries of patterns of grain dissolution that cannot be predicted with confidence.

Within the Lapita realm, the most notable example of intensive dissolution of calcareous grains is the sherd assemblage from Watom Island (Dickinson 2000) off the coast of New Britain where the first identifiable Lapita potsherds were recovered by the German missionary Otto Meyer in 1909. Many Watom sherd tempers described as volcanic sand, rather than as hybrid volcanic-calcareous sand, differ from the latter only because of partial or wholesale dissolution of calcareous grains. Recognition of widespread alteration of Watom temper compositions by grain dissolution has significantly influenced subsequent archaeological interpretations of the Watom sherd assemblage (Green & Anson 2000: 81–82).

The relative proportions of terrigenous and calcareous grains in Rove tempers are highly variable, as is common for hybrid sand temper suites in Pacific Oceania. The delivery of land-derived terrigenous and reef-derived calcareous sand to coastal island environments is subject to vagaries of waves and tides and currents in patterns that are virtually impossible to predict or hindcast. In addition, the sorting of sand grains by size and density during sand redistribution within local coastal settings partly controls the proportions of the two generic grain types at specific locales. The percentages of calcareous grains or vacuoles, or combined residual calcareous grains and vacuoles, varies in sectioned Rove sherds from maxima of >25 per cent, peaking at 45–65 per cent, downward to ~5 per cent or even less, with the mean content in the range of 10–25 per cent.

Variations in the abundance of calcareous grains and vacuoles can be detected by megascopic examination of sherds with a 10× hand lens. Surfaces and sawed sections of sherds containing >25 per cent preserved calcareous grains display abundant chalky white calcareous grains that contrast with darker and less weathered terrigenous grains. Sherds containing few residual calcareous grains and more abundant vacuoles left by dissolution of calcareous grains display sparse chalky white calcareous grains together with more abundant vacuole pits most prominent on sawed sherd surfaces but also visible on weathered sherd surfaces. Sherds containing no residual calcareous grains but 15–25 per cent derivative vacuoles display abundant and clearly visible vacuole pits on both weathered and sawed surfaces, but sherds lacking any residual calcareous grains and containing ≤10 per cent derivative vacuoles display quite rare vacuole pits discernible only by close scrutiny of sherd surfaces.

WAINIMALA OROGEN

Terrigenous (non-calcareous) grain types in Rove tempers are highly varied, including both monocrystalline grains of multiple mineral species and polycrystalline-polymineralic lithic fragments of diverse types. Their respective derivations can be understood in the context of the heterogeneous lithology of the Wainimala orogen as exposed within the Tuva River drainage basin in the hinterland of the Rove Peninsula (Figure 6).

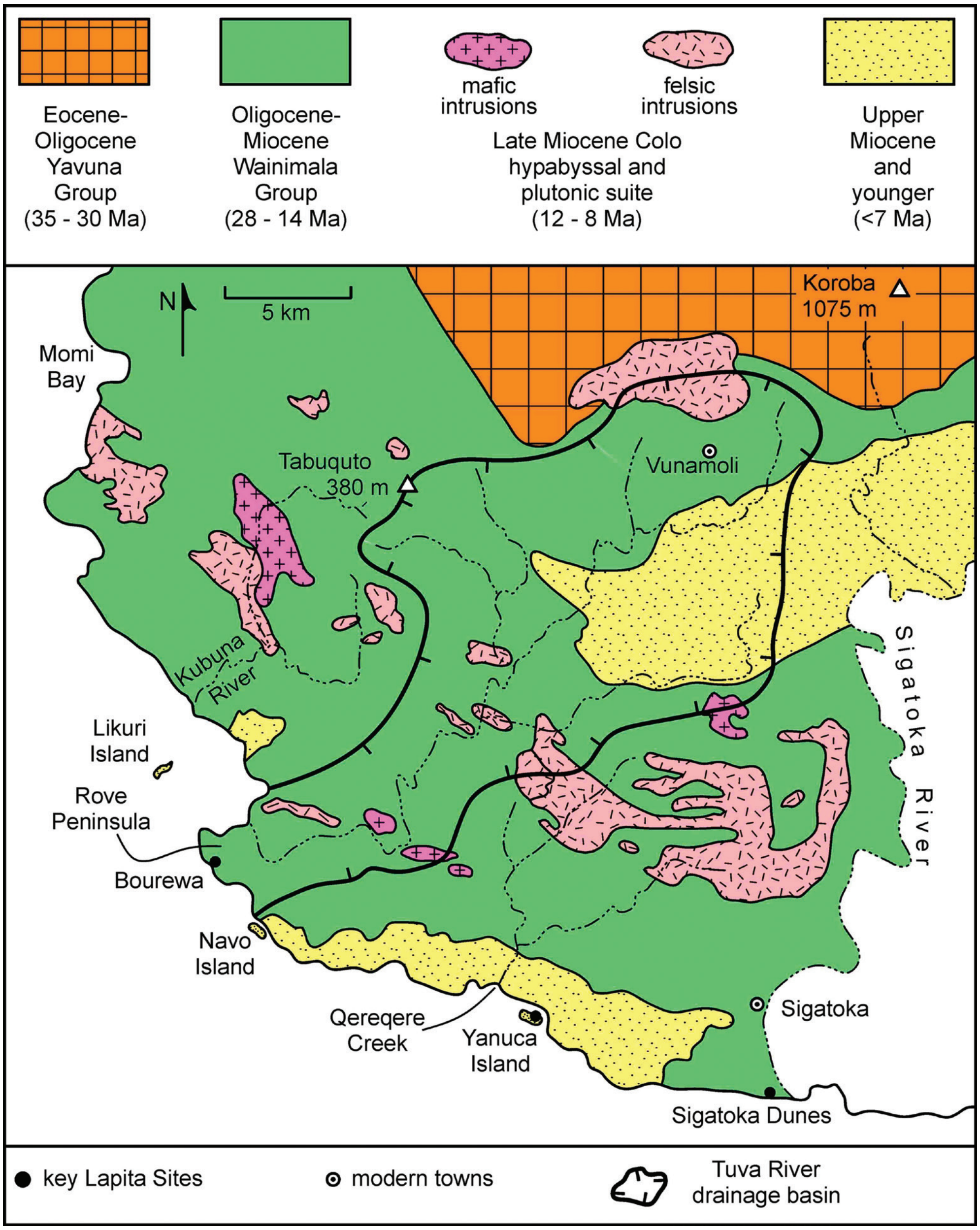

Figure 6. Geology of the hinterland of the Rove Peninsula in the drainages of the Tuva River and other streams of southwestern Viti Levu west of the Sigatoka River (see Figure 2 for location). Ages and distributions of geologic units adapted after Houtz (1959, 1960), Bartholomew (1960), Phillips (1965), Rodda and Band (1966), Whelan *et al.* (1985), Rodda & Lum (1990), Hathway (1994, 1995), and Wharton *et al.* (1995).

The Wainimala orogen is a vestigial segment of the Vitiaz island arc (Gill 1987), active in early Cenozoic time to link the ancestral Solomon Islands, Vanuatu (since rotated out of alignment by seafloor spreading in the North Fiji Basin), Fiji, and Tonga into a continuous geotectonic feature flanked on the northeast by the Vitiaz paleotrench (Dickinson 2006: Figure 9), which subducted Pacific seafloor downward to the southwest. The Oligocene–Miocene Wainimala Group forming the core of the orogen (Figure 2) is composed dominantly of strongly deformed volcanic and volcaniclastic strata metamorphosed variably in prehnite-pumpellyite to greenschist facies and cut by Colo igneous intrusions emplaced into the subterranean roots of the Vitiaz arc (Colley & Hindle 1984, Rodda & Lum 1990, Hathway 1994).

The Wainimala volcanic assemblage includes both lavas and breccias erupted partly by submarine volcanism and partly from subaerial volcanic edifices that rose above sea level at intervals along the Vitiaz arc (Wharton *et al.* 1995). The volcanogenic strata include tholeiitic (subalkalic) basalt, calkalkalic andesite and basaltic andesite, and minor dacitic differentiates. The stocks, dikes, and sills of the Colo intrusive suite include both mafic and felsic plutonic and hypabyssal igneous rocks (Colley & Hindle 1984, Whelan *et al.* 1985, Hathway 1994). The intrusive bodies aligned along a northwest–southeast belt crossing the Tuva River 10–15 km inland from Bourewa (Figure 6) mark the central magmatic axis of the ancestral Vitiaz arc, and were probably emplaced as subvolcanic intrusions beneath volcanic edifices that have since been removed by erosion (Hathway 1994). The forearc flank of the Vitiaz magmatic arc lay farther north near Vunamoli (Figure 6) where the Wainimala Group overlies the slightly older (Eocene–Oligocene) Yavuna Group of lithologically similar strata (Whelan *et al.* 1985, Hathway 1994). The deformed Wainimala Group reaches a net stratigraphic thickness approaching 5000 m and includes subordinate sedimentary and metasedimentary strata exposed as argillite, hornfels, chert, and reefal limestone intercalated locally with the dominant volcanic-volcaniclastic strata (Houtz 1959, Hathway 1994, Wharton *et al.* 1995). The widely separated pods and lenses of limestone are largely platform carbonates deposited on the flanks or atop the dormant crests of isolated volcanic edifices that rose toward sea level (Hathway 1994, 1995).

We have considered the possibility that some or all of the calcareous grains in Rove sherds are detrital limeclasts (reworked fragments of indurated limestone) from the Wainimala Group, but their internal textures preclude that interpretation. All the preserved calcareous grains are either skeletal grains displaying oriented calcite fabrics of organic origin or pelletal grains composed of unaltered micrite representing modern reef detritus. None are made of more coarsely crystalline microspar of diagenetic origin characteristic for reworked limeclasts. We infer that Wainimala limestones are removed by solution weathering as the tropical landscape of Viti Levu is lowered by erosion, and do not contribute fragmental limeclasts to local streams.

Intrusive bodies of the Colo igneous suite (Figure 6) include coarsely crystalline plutonic stocks of felsic (granitic) to mafic (gabbroic-dioritic) composition, but also much more finely crystalline hypabyssal microphanerites such as microgranite, microdiorite, dolerite, and the similar groundmasses of varied porphyries. Hornfelsed and silicified aureoles of contact metamorphic rock cut by abundant hypabyssal dikes and sills were developed around the margins of the larger stocks (Hathway 1994), and many of the plutonic stocks grade internally in texture to hypabyssal margins where intrusive magmas were chilled against Wainimala country rocks (Houtz 1959). It is difficult in the field to distinguish between metamorphosed Wainimala volcanic rocks exposed in contact aureoles and hypabyssal Colo intrusive rocks (Houtz 1960).

Distinction in thin section between volcanic lithic fragments and microgranular hypabyssal lithic fragments is dependent on the internal crystallinity of polycrystalline-polymminerallic lithic fragments, and is subject to operator judgment. Frequency percentages reported here for total igneous lithic fragments in Rove tempers are accordingly more reliable than relative percentages reported for lithic fragments derived respectively from volcanic and intrusive components of the Wainimala-Colo lithic assemblage.

ROVE TEMPER COMPOSITIONS

The terrigenous fractions of Rove tempers are representative of the dissected orogen temper class (Dickinson 2006: 13, 87–88) widespread at archaeological sites along the south coast of Viti Levu (Kumar *et al.* 2004, Dickinson 2006: 92–95). Rove temper compositions are among the most heterogeneous known from Oceanian potsherds, and properly classifying all the diverse grain types observed in Rove temper sands is petrographically challenging. Correctly identifying the monocrystalline sand grains requires close attention to optical properties (Dickinson 2006: Tables 2–3), and devising effective operational criteria for discrimination among the various generic categories of partly intergradational polycrystalline-polyminerallic lithic fragments based on their internal textures and fabrics stretches the limits of petrographic methodology. Table 2 is the scheme of grain classification adopted for this study of Rove temper compositions, and indicates the nature of Wainimala-Colo bedrock sources from which each temper grain type was derived. Assignment of different grain types to presumed bedrock sources is guided by knowledge that the Tuva River and its tributaries tap only the Wainimala orogen and younger Miocene cover strata derived from erosion of the Wainimala orogen (Figure 6).

Barring errors in determining optical properties, identifications of monocrystalline mineral grains are reli-

Table 2. *Temper grain types in Rove Peninsula sherds (Table 1). Abbreviations for Table 3 and Appendix. Derivation indicates inferred bedrock source(s) within the Wainimala orogen (Figures 2 and 6).*

Abbrev.	Description	Derivation
A. quartzose grains of low specific gravity		
MQZ	monocrystalline quartz grains	granitic rocks, felsic volcanic-metavolcanic or hypabyssal igneous rocks (phenocrystic), volcaniclastic rocks (recycled)
PQZ	polycrystalline quartz grains	vein quartz or granitic rocks
CQZ	chalcedonic (microcrystalline) quartz aggregates	sedimentary-metasedimentary (chert-metachert) and silicified volcanic rocks
B. feldspar mineral grains of low specific gravity		
PLG	plagioclase feldspar grains	intrusive igneous rocks (mafic or felsic), volcanic-metavolcanic or hypabyssal rocks (phenocrystic), volcaniclastic rocks
KSP	monocrystalline K-feldspar	granitic rocks, volcanic-metavolcanic rocks (phenocrystic), volcaniclastic rocks
C. ferromagnesian mineral grains of high specific gravity – FM [FS (ferromagnesian silicate minerals) = OLV + OPX + CPX + HBL + OXY + EPI + BIO]		
OPA	opaque iron oxide grains (magnetite, ilmenite)	multiple volcanic and intrusive igneous rock types
OLV	olivine mineral grains	mafic volcanic (phenocrystic) and intrusive igneous rocks
OPX	orthopyroxene mineral grains (dominantly hypersthene)	mafic volcanic (phenocrystic) and intrusive igneous rocks
CPX	clinopyroxene mineral grains (dominantly augite)	mafic volcanic (phenocrystic) and intrusive igneous rocks
HBL	hornblende mineral grains (exclusively green varieties)	volcanic (phenocrystic) and intrusive igneous rocks
OXY	oxyhornblende mineral grains (low extinction angle)	felsic or intermediate volcanic (phenocrystic) rocks
EPI	aggregate epidote grains (including clinozoisite)	plutonic or hypabyssal rocks (deuteric alteration), metavolcanic rocks
BIO	biotite (black mica) flakes	felsic plutonic or hypabyssal rocks
D. volcanic lithic fragments (polycrystalline and polyminerallic) – VLF		
VIT	Isotropic volcanic glass and cryptocrystalline alteration products	felsic (pale glass) and mafic (brown to red glass) volcanic rocks
FEL	felsitic (microcrystalline mosaic of quartz and feldspar)	felsic to intermediate volcanic-metavolcanic rocks
MIC	microlitic (untwinned plagioclase microlites set in volcanic glass)	intermediate to mafic volcanic-metavolcanic rocks
E. non-volcanic igneous lithic fragments (polycrystalline and polymineralllic) – ILF		
PLUT	microgranular grains of coarse plutonic igneous texture	granitic plutons of the Colo intrusive assemblage
HYPA	microgranular grains of fine hypabyssal igneous texture	intrusive dikes, sills, and stocks of the Colo intrusive assemblage
F. clastic sedimentary-metasedimenary lithic fragments – CLF		
CLAS	microgranular grains of fragmental (clastic) texture	volcaniclastic strata
ARGI	slate-argillite-hornfels (fine clastic-metaclastic textures)	sedimentary-metasedimentary rocks
TECT	metamorphic phyllite-schist with foliated tectonite fabrics	metasedimentary-metavolcanic rocks
G. calcareous reef detritus and proxy vacuoles		
CAL	skeletal and pelletal calcareous grains	N/A (derived from offshore fringing reef)
VAC	equant vacuoles (sand size and shape)	N/A (formed by dissolution of calcareous grains)

able and total frequency percentages reported for polycrystalline-polymineralllic lithic grains are robust, but relative proportions of different kinds of lithic fragments are partly dependent upon operator judgment. Relative compositional patterns and trends discussed in this paper are thought to be valid because all our petrographic data were generated by the same operator over the span of just a few months, but absolute percentages of different types of lithic fragments may well be imprecise.

ROVE TEMPER VARIANTS

Frequency counts of the terrigenous sand grains in Rove sherds (see Appendix) allows subdivision of the tempers into seven temper types:

(1) SNP: standard nonplacer tempers (n=27, or 51%);
(2) LNP: lithic nonplacer tempers (n=4, or 7%);
(3) SPP: partially placered standard tempers (n=7, or 13%);
(4) LPP: partially placered lithic tempers (n=3, or 6%);
(5) VLP: volcanic placer tempers (n=3, or 6%);
(6) PPT: pyroxenic placer tempers (n=6, or 11%);
(7) OPT: opaque-rich placer tempers (n=3, or 6%).

From their abundance in the Rove sherd suite, SNP tempers are assumed to be indigenous local tempers, and by analogy the closely related LNP-SPP-LPP tempers are regarded as variants of locally available temper sands collected in close proximity to the Rove Peninsula. Most placer tempers (PPT-OPT) can be interpreted as placer concentrates formed by coastal reworking of local nonplacer sands at selected unknown locales on the shores of the Tuva estuary (Figure 4B). The VLP tempers contrast strongly with the six other temper types and each is unique (VLP$_1$, VLP$_2$, VLP$_3$) in salient respects.

Contrasts in the bulk compositions of Rove temper types are controlled by variations in proportions of polycrystalline-polymineralic lithic fragments and in relative concentrations of ferromagnesian mineral grains of high specific gravity (Figure 7A). When temper compositions are recalculated without ferromagnesian grains to eliminate placering effects (Figure 7B), all temper types plot as a coherent array (Figure 7B), elongated by a threefold variation (30–90%) in proportions of lithic fragments superimposed upon a more consistent quartz/feldspar ratio of 45±20%. When polycrystalline-polymineralic lithic fragments are excluded from temper compositions (Figure 7C), the placer tempers plot in adjacent compositional fields toward which the partially placered standard tempers (SPP) are displaced from the field for standard nonplacer tempers (SNP). A reduction in lithic fragments, which include vitric volcanic lithic fragments of low specific gravity, also displaces the partially placered standard tempers (SPP) from most standard nonplacer tempers (SNP) on Figure 7B excluding ferromagnesian grains.

Relationships among the Rove temper types are clarified by tabulation of supplemental grain indices (Table 3). Mean values for an array of key grain indices overlap near 1σ for SNP, LNP, and SPP tempers (Table 4), thereby supporting the interpretation of a common sand provenance within the Wainimala orogen. They are interpreted as local sands indigenous to the vicinity of the Rove Peninsula. Most of the placer tempers (LPP, PPT, OPT) can be interpreted as placer concentrates from sands generically similar to the less placered temper types, hence also available locally at selected locales near the Rove Peninsula. Mean quartz (QZi) and feldspar (PFi) indices, largely unaffected by placering, overlap near 1σ for comparisons of the indigenous placer tempers (LPP, PPT, OPT) with less placered

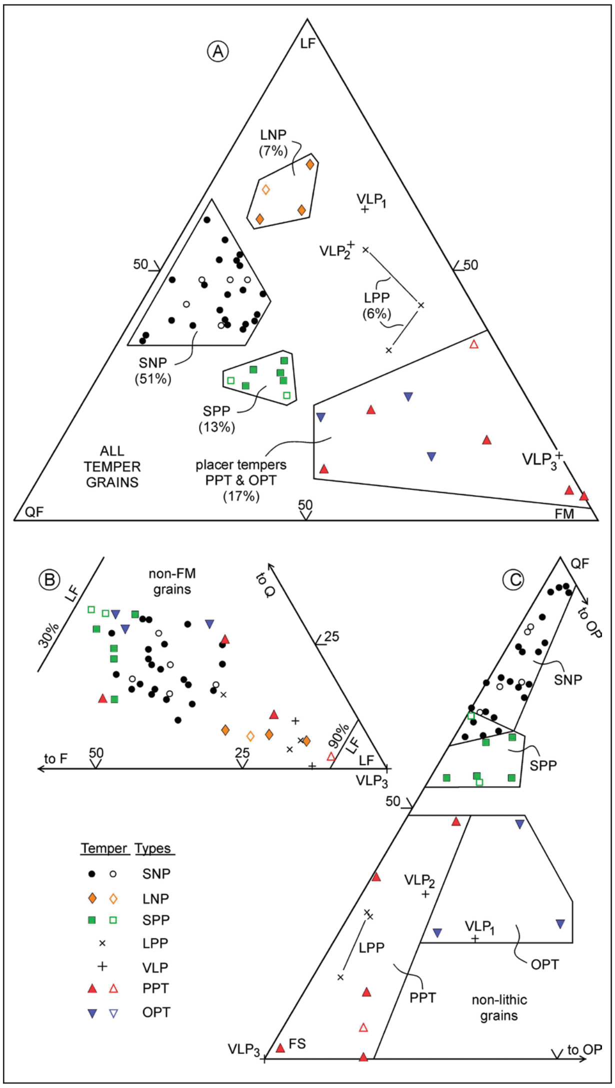

Figure 7. Ternary plots (Dickinson 2006: 28–29) of frequency percentages of grain types in Rove tempers (see Table 2 for grain types and text for temper types). Solid symbols are excavated sherds and open symbols are surface sherds. Poles for A (LF-QF-FM diagram): LF – total polycrystalline-polymineralic lithic fragments (PQZ + CQZ + VLF + ILF + CLF), QF – monocrystalline quartz-feldspar grains (MQZ + PLG + KSP), FM – total ferromagnesian mineral grains. Poles for B (Q-F-LF diagram): Q – monocrystalline quartz (MQZ), F – monocrystalline feldspar (PLG + KSP), LF – same as for A. Poles for C (QF-FS-OP diagram): QF – same as for A; FS – ferromagnesian silicate mineral grains (FM minus OPA); OP – opaque iron oxide grains (OPA). Lithic-rich LNP tempers not plotted in C. Note that exotic temper type VLP$_3$ plots at the LF pole in B and at the FS pole in C.

Table 3. *Supplemental grain indices (modified from Dickinson 2006: Table 6) for Rove tempers. See Table 2 for abbreviations of temper grain types.*

Parameter	Symbol	Definition (× 100)	Implication
mineral indices			
Quartz index	QZi	MQZ/(MQZ+PLG+KSP)	quartz/feldspar ratio
Feldspar index	PFi	PLG/(PLG+KSP)	plagioclase/K-feldspar ratio
Oxide index	OXi	OPA/FM [=OPA+FS]	ferromagnesian oxide/silicate ratio
Olivine index	OLi	OLV/FS [=FM–OPA]	olivine/ferromagnesian ratio
Pyribole index	PYi	(CPX+OPX)/(CPX+OPX+HBL+OXY)	pyroxene/hornblende ratio
lithic indices			
Quartzose index	QLi	(PQZ+CQZ)/(PQZ+CQZ+VLF+ILF+CLF)	quartzose lithic grain proportion
Volcanic index	VLi	VLF/(PQZ+CQZ+VLF+ILF+CLF)	volcanic lithic grain proportion
Intrusive index	InLi	(ILF+PQZ)/(PQZ+CQZ+VLF+ILF+CLF)	intrusive lithic grain proportion
Igneous index	IgLi	(VLF+ILF+PQZ)/(VLF+ILF+CLF+P-CQZ)	total igneous lithic grain proportion
Sedimentary index	SLi	(CLF+CQZ)/(PQZ+CQZ+VLF+ILF+CLF)	sedimentary lithic grain proportion
hybrid index	CVi	(CAL+VAC)/(CAL+VAC+terrigenous grains)	total initial calcareous grains

Table 4. *Values (± 1σ) of key supplemental grain indices (Table 3) for Rove temper types (see text for abbreviations) where N=number of sherds per subset. Ranges in parentheses.*

Type	N	CVi	QZi	PFi	PYi	VLi	InLi	IgLi	SLi
SNP	27	[1]15±7 (2–25)	42±9 (25–61)	81±3 (71–86)	[2]70±14 (44–100)	37±10 (22–54)	35±11 (15–57)	72±11 (62–90)	28±11 (10–53)
LNP	4	[1]20±7 (10–26)	29±5 (25–36)	78±3 (72–81)	70±14 (55–92)	46±6 (40–55)	30±2 (26–32)	75±7 (66–85)	25±7 (15–34)
SPP	7	17±8 (4–25)	46±12 (26–66)	79±4 (72–86)	77±13 (53–100)	42±11 (31–62)	36±11 (20–54)	75±9 (62–93)	25±9 (7–38)
LPP	3	16±9 (3–23)	33±8 (23–42)	82±1 (80–83)	95±2 (93–98)	46±6 (38–53)	30±3 (26–33)	75±5 (68–79)	25±5 (21–32)
PPT	6	[1]14±8 (5–22)	[3]45±17 (25–64)	[4]79±3 (76–82)	98±2 (94–100)	[5]62±12 (50–83)	[5]28±8 (14–36)	[5]90±4 (86–97)	[5]10±4 (3–14)
OPT	3	10±3 (8–14)	53±9 (43–65)	78±5 (71–82)	52±7 (44–61)	54±6 (48–62)	29±13 (15–47)	83±9 (76–95)	17±9 (5–24)
[6]VLP$_1$	1	11	0	100	55	100	0	100	0
[7]VLP$_2$	1	11	50	100	100	100	0	100	0
[8]VLP$_3$	1	0	0	N/A[9]	99	100	0	100	0

1 Calculated from tempers with CVi ≤26 [≤26% (CAL + VAC)]
2 Calculated from 18 SNP tempers containing ≥5% total pyriboles
3 Calculated from 5 PPT tempers containing MQZ grains
4 Calculated from 2 PPT tempers containing ≥5% feldspar grains
5 Calculated from 4 PPT tempers containing ≥10% lithic fragments
6 Sherd QR2F from 135 cm depth in Qoqo Area Pit R2
7 Sherd BO22 from 75 cm depth in Bourewa Area Pit ×20
8 Sherd BO21 from 65 cm depth in Bourewa Area Pit ×14
9 Only a trace (<1%) plagioclase feldspar grains and no K-feldspar

local temper types (SNP, LNP, SPP). Higher pyribole indices (PYi) for some of the indigenous placer tempers (LPP, PPT), as compared to indigenous nonplacer tempers, is inferred to reflect reduction in the pyroxene/hornblende ratio of placer sands by removal of more cleavable hornblende grains during placer reworking. Similarly, enhancements in volcanic (VLi) and igneous (IgLi) indices for the indigenous placer tempers, together with complementary reductions in the sedimentary index (SLi), are inferred to reflect disintegration of clastic and argillitic grains during placer reworking. Grain indices for the three volcanic placer tempers (VLP) contrast strongly with those for the other six temper types (Table 4) used for the production of indigenous pottery on the Rove Peninsula. The VLP tempers are interpreted as non-local tempers not derived from Wainimala-Colo sources.

Potters from the Rove Peninsula may have ranged as far afield as the mouth of the Kubuna River (Figure 6) to collect temper sand, but the nature of upstream Wainimala-Colo source rocks for Kubuna sand, and for sands delivered to the coast of southwest Viti Levu by smaller streams, does not differ substantially from exposures in the Tuva River drainage debouching on the eastern side of the Rove Peninsula. Temper analysis is unsuited to test how far from the Rove Peninsula dissected orogen temper sands may have been collected for local pottery production because the provenance of stream and coastal sands is not expected to vary significantly along the coast of southwest Viti Levu anywhere west of the Sigatoka River (Figure 6). The occurrence of three Lapita potsherds within predominantly silty clay cultural strata at the Matelita Tree site (Figure 4) on the Rove Peninsula may indicate that local clay deposits were one source of the clay bodies used for the production of Rove earthenware.

There is no evidence that the distribution of different temper types in Rove sherds is systematic by either subsite or depth in excavations (Table 5). SNP tempers are the most common at nearly all subsites and depths, and the other indigenous tempers (LNP, SPP, LPP, PPT, OPT) occur seemingly at random with respect to both subsites and depths. Potters on the Rove Peninsula were apparently able to access the same variety of local temper sands on coasts surrounding the Tuva estuary (Figure 4B) throughout the Lapita interval.

NON-LOCAL TEMPERS

Each of the VLP tempers (VLP1, VLP2, VLP3) is unique in the Rove temper suite, but all differ generically from the six temper types inferred to be local tempers used for making indigenous pottery on the Rove Peninsula. The generic differences are not readily apparent on ternary diagrams of temper composition (Figure 7), but are highlighted by contrasting grain indices (Table 4). The VLP tempers are all exclusively volcanic sands (VLi=100) containing no intrusive or sedimentary lithic fragments (InLi=SLi=0), two contain no quartz (QZi=0), two contain no amphibole (PYi=100), and feldspar is exclusively plagioclase (PFi=100).

There is no likelihood that the VLP temper sands were transported to any segment of the Viti Levu coast near the Rove Peninsula by the Tuva River or other drainages. The Rove sherds containing anomalous VLP tempers instead provide evidence for ceramic transfer to the Rove Peninsula from Lapita settlements elsewhere in Fiji. Lapita expansion within Fiji was likely incremental and involved only small individual settlements (Clark & Anderson 2009b, Cochrane *et al.* 2011). Given the apparent primacy of Bourewa as the oldest Lapita site on Viti Levu, the largest landmass in Fiji, occupants of other Fijian Lapita sites are likely to have had cultural or even familial ties to people living at Bourewa or nearby settlements on the Rove Peninsula.

Table 5. *Distribution by subsite (Figure 4) and by depth in excavations (Table 1) of temper types (see text for abbreviations) in subsets of sherds examined in thin section from the Rove Peninsula*

Subset	SNP	LNP	SPP	LPP	VLP	PPT	OPT
A. By subsites and Bourewa subareas							
Bourewa surface	2	–	1	–	–	–	–
Bourewa A Pits	4	2	3	–	–	1	–
Bourewa C Pits	1	–	–	–	–	1	–
Bourewa J-L-P Pits	1	–	1	2	–	–	–
Bourewa Pits RB2-RB3	4	–	–	–	–	–	1
Bourewa Pit TP5	1	–	–	–	–	2	
Bourewa X Pits	5	1	1	–	2	1	2
Bourewa Y-Z Pits	1	–	–	1	–	–	–
Qoqo subsite	6	1	1	–	1	–	–
Tomato Patch subsite	2	–	–	–	–	1	–
Totals	**27**	**4**	**7**	**3**	**3**	**6**	**3**
B. By depth in cm (±5 cm)							
0–25 cm (surface and shallow)	7	2	2	–	–	1	1
35–65 cm (intermediate depths)	9	–	1	2	1	3	–
75–105 cm (deeper horizons)	4	2	4	–	1	2	1
115–205 cm (deepest horizons)	7	–	–	1	1	–	1
Totals	**27**	**4**	**7**	**3**	**3**	**6**	**3**

The Period A occupation at Bourewa spanned the interval 3140–2795 calBP (Nunn 2007) when few other Lapita sites in Fiji were yet established (Figure 3), but none of the Rove sherds containing VLP tempers date from that earliest occupancy. Sherd BO22 (VLP_2 temper of Table 4) was recovered at a depth of 75 cm in Bourewa Pit X20 where conventional radiocarbon ages at 60–70 cm depth are 2976–2831 BP, calibrating at 2σ to 2825–2370 calBP (Nunn 2007) or 2850–2470 calBP (Clark & Anderson 2009a). Sherd BO21 (VLP_3 temper of Table 4) derives from a comparable depth of 65 cm in Pit X14 dug <10 m north of Pit X20 (Nunn 2007). These relations suggest that the sherds containing VLP_2 and VLP_3 tempers date from the Period B occupation at Bourewa spanning the interval 2940–2670 calBP (Nunn 2007), by which time multiple Lapita settlements had been founded within Fiji (Figure 3). The two sherds might even date from the early part of Period C spanning the interval 2775–2360 calBP (Nunn 2007) and extending into the Late Lapita ceramic phase. The age of the Qoqo sherd QR2F containing temper type VLP_1 from deep in Pit R2 is not closely controlled by radiocarbon dating, but the earliest occupancy of the Qoqo subsite probably occurred during Bourewa Period B at perhaps 2850 calBP (Nunn 2007). Further development at Qoqo, Bourewa expansion, and the occupation of subsites southeast of Bourewa (Figure 4) continued through Period C (Nunn 2007). These considerations encourage inquiry into possible affinities of the VLP tempers with other known Lapita temper suites within Fiji.

The PYi index for temper type VLP_1 is distinctly less than the mean PYi indices of all the indigenous Rove tempers (Table 4). Moreover, the hornblende in temper type VLP_1 is largely brown hornblende, whereas the hornblende in all local Rove tempers of indigenous wares is exclusively green hornblende. Temper type VLP_1 also contains 2% oxyhornblende (25% of the amphibole population), which was not observed in more than trace amounts (≤1%) in any other Rove tempers. Fijian hornblendic volcanic sand tempers containing abundant oxyhornblende are known only from Kadavu (Dickinson 2012), the large island ~150 km southeast of the Rove Peninsula (Figure 2). No Lapita sites have yet been excavated on Kadavu, but Late Lapita ceramics dating provisionally to ~2600 cal yr BP have been collected from the surface at multiple sites on Kadavu (Burley 2012). Excavation of Kadavu Lapita sites is needed to understand Kadavu ceramic relations better, but exotic sherds presumed to derive from Kadavu have also been identified at the Lapita site of Naitabale (Figures 2–3) on Moturiki Island (Kumar 2006, Nunn *et al.* 2007). An inferred Kadavu origin for VLP_1 temper is supported by the presence of biotite in the temper sand (see Appendix). Biotite is prominent in three-quarters of the volcanic sand tempers in sherds of various ages studied from Kadavu (Dickinson 2012), but Kadavu is the only locale within Fiji where biotite is a significant component of volcanic sand tempers. Nor is biotite prominent in tempers from island Melanesia to the west or from Tonga and Samoa to the east (Dickinson 2006). Temper analysis thus implies probable origin of sherd QR2F from Kadavu.

The pyroxenic temper type VLP_2 is an exclusively volcanic sand in which ~80% of the volcanic lithic fragments are composed entirely of brown volcanic glass or its cryptocrystalline alteration products. Derivation of Sherd BO22 from anywhere on southern Viti Levu is highly unlikely, but an origin on northern Viti Levu or on Vanua Levu where pyroxenic volcanic sands are common as temper is probably feasible. Exclusively pyroxenic volcanic sands also occur in sherds collected from the surface on the coast of eastern Kadavu at Tiliva Resort (Burley 2010, 2012b; Dickinson 2012), and a surface sherd from nearby Tiliva Village is rich in brown vitric lithic fragments similar to those in VLP_2 temper. The derivation of sherds containing both VLP_1 and VLP_2 tempers from Kadavu is an attractively parsimonious interpretation, although not a robust postulate because pyroxenic volcanic sands were used for temper in many parts of prehistoric Fiji. The hybrid character (CVi=11 from Table 4) of VLP_1 and VLP_2 temper sands does not preclude derivation from Kadavu because four of six surface sherds from Tiliva Resort and nearby Tiliva Village (Dickinson 2012) contain either calcareous grains or proxy vacuoles indicative of hybrid sand.

The well sorted placer temper VLP_3 in sherd BO21 is quite distinctive texturally as well as mineralogically from the tempers in all other Rove sherds. Frequency percentages of grain types were determined by an areal traverse count (Middleton *et al.* 1985) of 400 grains to generate compositional data methodologically equivalent to the data available for broadly similar placer tempers of volcanic sand from many Oceanian locales (Dickinson 2007). Special treatment for the sherd was designed to test the possibility that it might have been derived from Nëndo in the Santa Cruz Group ~1500 km northwest of Viti Levu (Figure 1) because the sherd is decorated by motifs suggestive of Western Lapita wares from island Melanesia.

Comparative compositional data preclude derivation of temper type VLP_3 from the Santa Cruz Group on the basis of contrasting olivine (OLi) and oxide (OXi) indices (Table 6). Nor are known Lapita placer tempers from Erromango in southern Vanuatu a feasible match for VLP_3 temper, notably from lack of hornblende as well as paucity of olivine (Table 6). Apart from the Erromango Lapita sherds, all known placer tempers in both Lapita and post-Lapita wares of Vanuatu consistently contain excessive hornblende (PYi ≤90) as compared to VLP_3 temper (Dickinson 2001). Placer tempers from the Bismarck Archipelago (Dickinson 2002, 2007) either lack olivine entirely (OLi=0) or contain orthopyroxene as well as clinopyroxene in addition to minor olivine (OLi=1–3). The corpus of petrographic data for Bismarck tempers now includes 295 sherds from 18 different islands or closely associated island clusters (Dickinson 2006: 139), and none of the 60 known Bismarck placer tempers (Dickinson 2007) resemble tem-

Table 6. *Comparison of the mineralogical compositions of the non-local placer sand temper of volcanic derivation in Bourewa Sherd BO21 (Table 4 footnote) and comparably pyroxenic placer tempers (PYi ≥99) in Lapita sherds from other sites. See Table 1 for abbreviations of grain types, Table 3 for definitions of olivine index (OLi) and oxide index (OXi), and Figure 2 for locations of Natunuku on the north coast of Viti Levu, Vorovoro on an islet off the coast of Vanua Levu, and Votua on Mago in the Lau Archipelago.*

		sites in the New Hebrides island arc			central Fiji sites		Lau-Lomativiti sites	
Grains	Bourewa[1]	Nëndo[2]	Reef Islands[3]	Erromango[4]	Natunuku[5]	Vorovoro[6]	Votua[7]	Kedekede[8]
CPX	72	66	77	72	72	58	69	89
OLV	8	3	4	5	7	1	4	3
HBL	tr	1	tr	0	tr	1	0	0
OPA	11	3	2	14	13	2	4	3
PLG	tr	11	7	4	1	25	11	1
VRF	8	16	10	5	7	13	12	4
OLi	10	4	5	6	10	2	5	3
OXi	12	4	2	15	14	3	5	3

1 Sherd BO21 from 65 cm depth in Bourewa Pit X14
2 Sherd SZ-8–125/5 provided by Roger Green in 1972 from the Nanggu site on Nëndo island in the Santa Cruz Group
3 Sherd RL-6–24/1 provided by Roger Green in 1972 from a site in the Reef Islands but also derived from Nëndo
4 Mean of two sherds provided by Matthew Spriggs in 1997 from Ponamla and Ifo sites on Erromango (Vanuatu)
5 Mean of sherds 22–5 and 22–35 containing Tavua volcano temper provided by Elizabeth Hinds (nee Shaw) in 1967
6 Mean of four excavated sherds provided by David Burley in 2011 (taken from an unpublished petrographic report)
7 Mean of two excavated sherds provided by Atholl Anderson and Geoffrey Clark in 1997 from Votua on Mago
8 Mean of eight *kedekede* tempers probably derived from Kanacea in the Lau Archipelago (Figure 2) but collected at multiple locales on Moturiki, Naigani, Lakeba, and Kabara islands in eastern Fiji (Dickinson 2006: 117)

per type VLP3. Placer tempers from Roviana Lagoon in the Solomon Islands contain excessive olivine (OLi>20). With present information, there are no petrographic grounds to suppose that Sherd BO21 containing VLP3 temper was derived from a legacy vessel handed down to Fiji from an ancestral homeland somewhere within island Melanesia. Its origin is more appropriately sought within Fiji.

A close temper compositional match is found for sherds from Natunuku on the north coast of Viti Levu containing Tavua volcano temper (Table 6). Other pyroxenic placer tempers in sherds collected from farther north (Vorovoro) or east (Votua, *kedekede* temper) in Fiji have lower olivine and oxide indices (OLi and OXi both ≤5). Untabulated Lapita and post-Lapita placer tempers from other sherd collections made on the north coast of Viti Levu (Dickinson 2007), including Vatia volcano temper at Natunuku, contain excessive hornblende (PYi≤80) for congruence with VLP3 temper despite an overall similarity in olivine content (OLi=7–11). Placer sand tempers in sherds from Matanamuani on Naigani and from Naitabale on Moturiki (Figure 2) lack olivine and are also untabulated. An origin for VLP3 temper east of Fiji can be excluded because the pyroxene in Tongan placer tempers is ~15% orthopyroxene, not present at all in VLP3 temper, and Samoan placer tempers contain excessive olivine, with OLi=30–80 (Dickinson 2007). Placer tempers in sherds from Futuna (Dickinson 2006, 2007) along the Melanesian borderland north of Fiji and west of Samoa contain no olivine (OLi=0) and are excessively rich in opaque grains (OXi=55). The Lapita settlement at Natunuku (Figure 2) is accordingly identified provisionally as the place from which the vessel yielding Bourewa Sherd BO21 was derived. Ceramic transfer from Natunuku to Bourewa would be possible by canoe voyages in sheltered waters near the Viti Levu coast without the risk of damage to fragile ceramic vessels entailed by voyages through rougher waters in open seas.

COMPARATIVE PETROGRAPHY

The abundant SNP tempers, present in half the Rove sherds, are essentially indistinguishable compositionally from tempers in sherds from the Yanuca Lapita site (Figure 8), located ~15 km east of Bourewa on an islet just off the coast of southwest Viti Levu (Figure 6). The congruence in composition is expected because Qereqere Creek, which debouches on the coast at Yanuca, also drains a provenance exposing only the Wainimala Group intruded by Colo plutons. More placered Rove tempers converge in composition with tempers in sherds from the Sigatoka sand dune site at the mouth of the Sigatoka River farther east (Burley & Dickinson 2004). Sigatoka tempers, however, are sands that were transported down the Sigatoka River, a much larger river than the Tuva River, and are consistently better sorted than Rove and Yanuca tempers. Another well studied dissected orogen temper in post-Lapita sherds from Nasilai on the Rewa Delta east of Suva (Figure 2) on southeast Viti Levu is substantially less lithic than tempers from southwest Viti Levu (Figure 8).

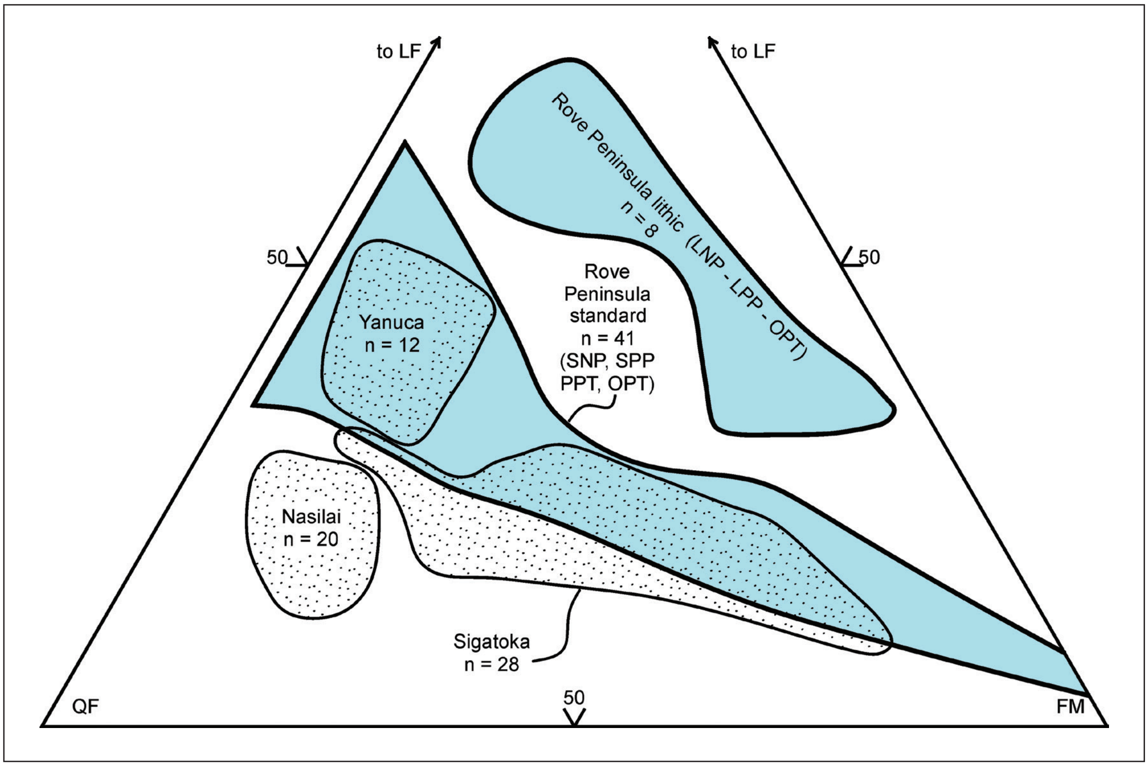

Figure 8. LF-QF-FM diagram of selected dissected orogen tempers from southern Viti Levu (see Figure 7A for ternary poles). Rove Peninsula compositional fields from this paper. Fields for Yanuca, Sigatoka, and Nasilai tempers after Dickinson (2006: Figure 36).

Our petrographic data are at variance in several respects with data reported by Rutherford *et al.* (2012) for 15 surface sherds collected at or near Bourewa. We cannot be confident that the materials used for this study are comparable to the materials they used, but we have detected no systematic dichotomies between the tempers of surface sherds and excavated sherds (Figure 7). If the two sherd subsets are analogous, the census of temper grain types reported by Rutherford *et al.* (2012: Table 1) is incomplete, for they reported no polycrystalline-polymineralllic lithic fragments, whereas this study documents the presence of 36–71 per cent lithic fragments among the terrigenous temper grains of nonplacer Rove tempers, 25–54 per cent for partially placered tempers, and 5–35 per cent for placer tempers (see Appendix). Rutherford *et al.* (2012) reported the presence of calcareous grains in two-thirds of the sherds they studied, but did not appreciate the proxy significance of vacuoles as a record of dissolution of calcareous grains from other sherds. Rutherford *et al.* (2012) further treated temper grains as integral constituents of Bourewa clay bodies, rather than as manually added temper sand. There are also significant discrepancies between the temper mineralogy reported by Rutherford *et al.* (2012) and that determined for this paper (Table 7). The discrepancies call some of their mineral identifications into question:

(1) the mineral reported as olivine (colorless in thin section), is rare in either the Wainimala Group or Colo plutons (Houtz 1959, 1960), is readily destroyed by tropical weathering, and may instead be pale green clinopyroxene, the dominant ferromagnesian silicate (FS) of indigenous Rove tempers, accounting for 73 per cent of the net FS population whereas the olivine content is <1 per cent overall;

(2) orthopyroxene was reported to the exclusion of clinopyroxene, although the ratio of the latter to the former is >50:1 in the frequency counts made for this paper and no known Oceanian tempers contain more orthopyroxene than clinopyroxene (Dickinson 2007);

(3) neither hornblende nor epidote was reported, although both minerals are present jointly in 70 per cent of the thin sections examined for this paper;

(4) the crystallographically disordered volcanic mineral sanidine was reported as dominant among K-feldspar grains, but the presence of minor sanidine with anomalously low optic axial angle could be confirmed for <5 per cent of K-feldspar grains during frequency counting for this paper, with most K-feldspar identified instead as orthoclase, probably derived mainly from Colo intrusive rocks rather than from Wainimala volcanic rocks in which phenocrystic K-feldspar is rare (Houtz 1959, 1960).

The identification of two rare minerals (monticellite and kaersutite) in Bourewa temper aggregates by Ruther-

Table 7. *Contrasting mineralogy of terrigenous grain types as reported by Rutherford et al. (2012) and in this paper (see Appendix) for local tempers of indigenous Rove Peninsula sherds.*

Mineral species	**Rutherford *et al*. (N=15 sherds)**	**this paper (N=50 sherds)**
Quartz	present in all sherds	1–31% in all sherds except one placer temper (BO20)
Plagioclase	present in 80% of sherds	1–28% in all sherds except one placer temper (BO20)
K-Feldspar	present in 73% of sherds, almost entirely as volcanic sanidine	1–7% in all sherds except four placer tempers, but dominantly intrusive orthoclase (95+% of net Kspar)
Olivine	present in 60% of sherds	present in trace amounts (1–2%) in only 10% of sherds
Orthopyroxene	present in 33% of sherds	present in trace amounts (1–3%) in only 25% of sherds
Clinopyroxene	unreported	1%-80% in all sherds except one nonplacer temper; dominant ferromagnesian silicate mineral (73% of net FS)
Hornblende	unreported	1–18% (mean 4%) in 84% of sherds
Epidote	unreported	1–5% (mean 2.5%) in 78% of sherds
Monticellite	present in 33% of sherds	undetected rare mineral unreported from other sedimentary aggregates globally (e.g., Mange & Wright 2007)
Kaersutite	present in 20% of sherds	undetected except as unspecified oxyhornblende in trace amounts (~1%) in two placer tempers (BO28, BO31)

ford *et al.* (2012) is also questionable (Table 7). Monticellite ($MgSiO_4$) is compositionally similar to magnesian olivine (Mg_2SiO_4) but occurs only in carbonatites, alkalic ultramafic lavas, and contact skarns, none of which occur within the Wainimala-Colo lithic assemblage. Moreover, monticellite weathers readily and has not been reported from any sedimentary aggregates elsewhere (e.g., Mange & Wright 2007). Positive identification of monticellite from optical microscopy alone, without using more sophisticated mineralogical techniques, may not be feasible. Kaersutite (Table 7) is a titaniferous variety of oxyhornblende, with which it shares most optical properties. Specific identification of kaersutite based on optical microscopy alone is probably not feasible. The mineral reported as kaersutite may conceivably be biotite, which has similar optical properties and occurs sparingly in Rove tempers (see Appendix).

SUMMARY CONCLUSIONS

As at most Lapita sites, the bulk of the ceramic assemblage (~95 per cent) from the Rove Peninsula is indigenous ware fabricated using local temper sand collected from the shores of the nearby Tuva estuary, either on the Viti Levu mainland or on Vusama paleoisland. Inferrred temper sources would have been accessible to potters from the Rove Peninsula traveling either on foot or by paddle canoe. The local tempers of indigenous Rove pottery were initially hybrid sands composed of mixtures of terrigenous and calcareous grains in varied proportions, but post-depositional dissolution has largely or entirely removed the calcareous grains to leave vacuoles in Rove sherds that now contain mostly or exclusively terrigenous temper grains. The terrigenous detritus was derived from the Wainimala Group and Colo intrusions that jointly form the Wainimala orogen forming the complex bedrock assemblage of southwest Viti Levu, and was brought to the coast by the Tuva River. The calcareous detritus was washed landward from the prominent reef flats fringing the Rove Peninsula. Three Rove sherds contain non-local volcanic sand tempers that could not have been derived from the Wainimala orogen, and are interpreted as a record of limited ceramic transfer to the Rove Peninsula during later phases of its prehistoric occupation from poorly known Lapita sites on Kadavu and from the Natunuku Lapita site on the north coast of Viti Levu. Indigenous Rove tempers belong to a spectrum of dissected orogen tempers contained in ceramic assemblages distributed along the south coast of Viti Levu. A recent study of Bourewa tempers by others provided an incomplete and in part questionable census of temper mineralogy. This study provides an improved assessment of the grain types in Rove sherds that should prove useful for future temper analysis of Lapita ceramic assemblages from Fiji.

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