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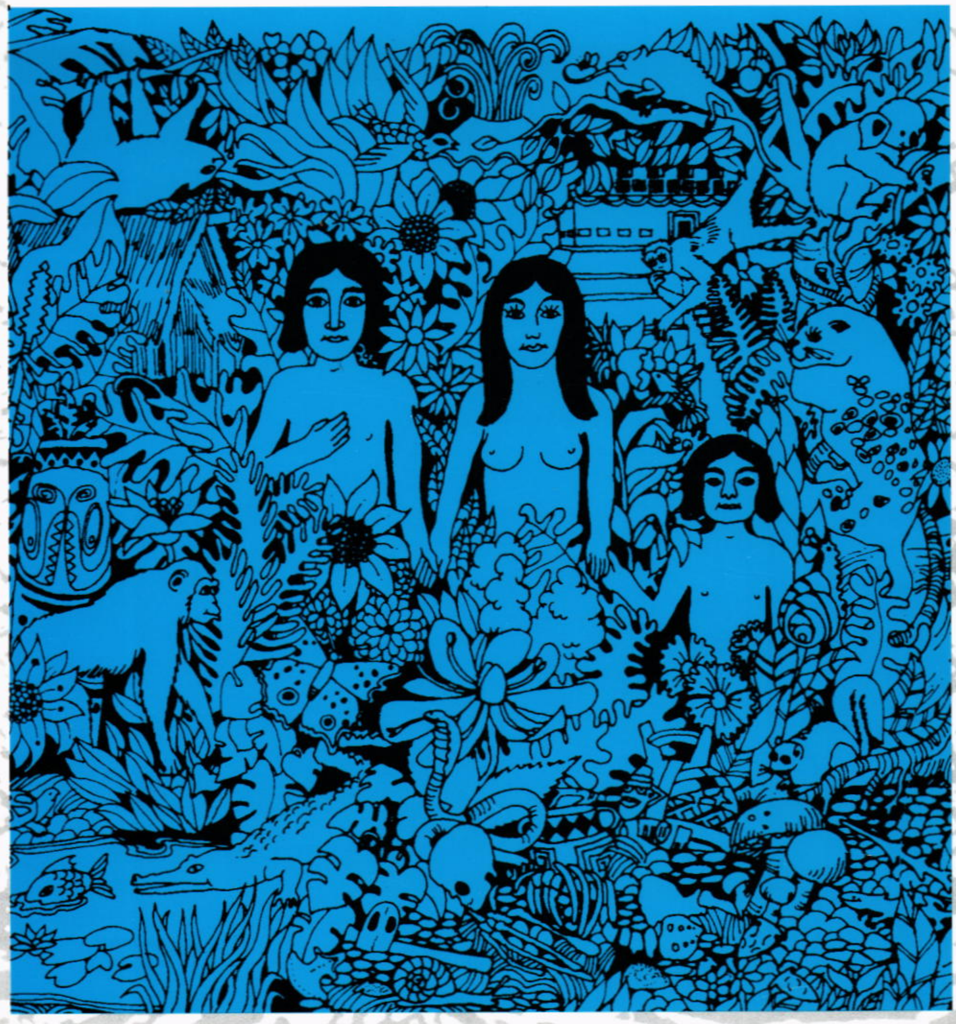

FIFTY YEARS IN THE FIELD. ESSAYS IN HONOUR AND CELEBRATION OF RICHARD SHUTLER JR'S ARCHAEOLOGICAL CAREER

Edited by Stuart Bedford, Christophe Sand and David Burley

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NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION MONOGRAPH

PETROLOGIC CHARACTER AND GEOLOGIC SOURCES OF SAND TEMPERS IN PREHISTORIC NEW CALEDONIAN POTTERY

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Temper sands in prehistoric potsherds from New Caledonia (Grande Terre) are petrologically distinctive from all the varied temper sands in sherds from other island groups of the southwest Pacific region. New Caledonia is a microcontinental fragment calved from the paleo-Pacific margin of Gondwanaland by seafloor spreading within the Tasman Sea, whereas all the other island groups are intraoceanic island arcs or seamount chains dissected to varying degrees by erosion, but containing no crustal underpinnings of continental derivation.

New Caledonian tempers, all of the *tectonic highland* temper class, include two end-member subclasses (Dickinson and Shutler 1968, 1971, 1979, 2000): (1) *quartzose* tempers composed dominantly of monocrystalline quartz mineral grains and quartzose (polycrystalline) sedimentary or metasedimentary lithic fragments; (2) *ophiolitic* tempers composed of mafic igneous and ultramafic detritus. Intermediate temper types contain both quartzose and ophiolitic debris in widely variable proportions. The mineralogical compositions of New Caledonian tempers were described briefly by Galipaud (1990) and Dickinson (1998), but not correlated closely with the bedrock geology of the Grande Terre. This study evaluates geologic sources for the overall range of New Caledonian temper types using a suite of 46 typical sherds provided by Richard Shutler Jr., and four other sherds provided by Christophe Sand.

GEOTECTONIC BACKGROUND

New Caledonia lies near the outer fringe of a bathymetrically complex belt of submerged ridges and intervening troughs lying east of the Australian continental block (Figure 1A). The outer fringe of the belt connects the Papuan Peninsula of the Papua New Guinea mainland with the microcontinental block formed by New Zealand and adjacent bathymetric plateaus. Farther off the Australia–New Guinea continental block from New Caledonia and the Papuan Peninsula, including its submerged extensions south of the Solomon Sea, other segments of Island Melanesia (Admiralty archipelago, Solomon chain, Vanuatu) are intraoceanic island arcs of so-called "reversed polarity", subducting seafloor of marginal basins downward to the northeast away from Australia (Figure 1A). Islands still farther east in Fiji, Tonga, and Samoa are also intraoceanic edifices lacking any continental basement.

As far outboard, however, as the Papuan Peninsula, New Caledonia, and New Zealand, all the diverse bathymetric ridges and their capping islands were dispersed by rifting and seafloor spreading from initial positions along the rim of the Gondwanan continental mass (Figure 1B). The principal drifting of continental slivers that form the various bathymetric ridges, including the Norfolk Ridge capped at its northern end by New Caledonia, occurred in response to seafloor spreading within the Tasman Sea from Late Cretaceous (85 Ma) to earliest Eocene (53 Ma), and within the Coral Sea from mid-Paleocene (61 Ma) to earliest Eocene (53 Ma). Subsequent local seafloor spreading within the Norfolk Basin calved the Three Kings Rise off the Norfolk Ridge in Miocene time, and in Pliocene time split the offshore extension of the Papuan Peninsula into two bathymetric rises separated by the Woodlark Basin (Figure 1A). Farther south, initial rifting of Australia from Antarctica began in Late Cretaceous time, and continental separation was complete by mid-Eocene time. The two continents continue to drift apart today, with the belt of bathymetric ridges offshore from Australia currently traveling away from Antarctica in lockstep with Australia.

Rocks exposed on New Caledonia include two contrasting geotectonic suites: (1) basal terranes formed along the rim of the Gondwanan continent before drift of the Norfolk Ridge away from Australia, and (2) structurally higher rock masses emplaced, or developed in place, during late Eocene overthrusting of an ophiolitic slab of oceanic lithosphere from northeast to southwest (Collot *et al.* 1987) across New Caledonia after its drift to an intraoceanic position. Ophiolite refers to the association of ultramafic peridotite, representing oceanic mantle, and

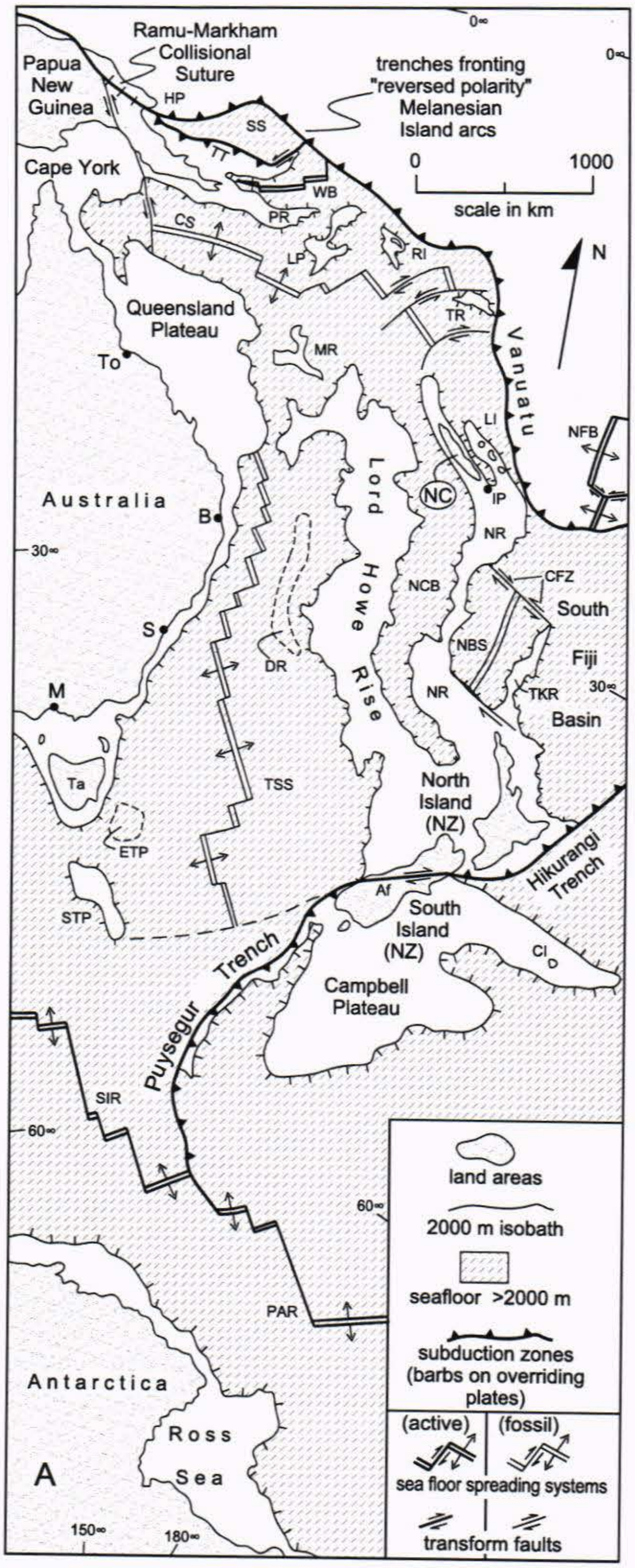

FIGURE 1 KEY: Active seafloor spreading systems: NFB, North Fiji Basin; PAR, Pacific-Antarctic Ridge; SIR, Southeast Indian Ridge; WB, Woodlark Basin. Fossil seafloor spreading systems: CSS, Coral Sea (eastern extensions inferred from distribution of shallow rises separated by deep seafloor); NBS, Norfolk Basin; TSS, Tasman Sea. Geotectonic relations and reconstructions adapted after Davies *et al.* (1985), Gaina *et al.* (1998), Mortimer *et al.* (1998), Muller *et al.* (2000), Shaw (1978), Sutherland (1999), Taylor and Falvey (1977), Taylor *et al.* (1995) and Uruski and Wood (1991). Selected features: Af, Alpine fault; B, Brisbane; CFZ, Cook Fracture Zone; CI, Chatham Islands; CY, Cape York; ETP, East Tasman Plateau (crest <3000m depth); DR, Dampier Ridge (crest <3000m depth); HP, Huon Peninsula; IP, Ile des Pins; LI, Loyalty Islands; LP, Louisiade Plateau; M, Melbourne; MR, Mellish Rise; NCB, New Caledonia Basin; NI, North Island (New Zealand); NR, Norfolk Ridge; PNG, Papua New Guinea; PR, Pocklington Rise; RI, Rennell Island; S, Sydney; SI, South Island (New Zealand); SS, Solomon Sea; STP, South Tasman Plateau; Ta, Tasmania; TKR, Three Kings Rise; To, Townsville; TR, Torres Rise; TT, Trobriand Trough.

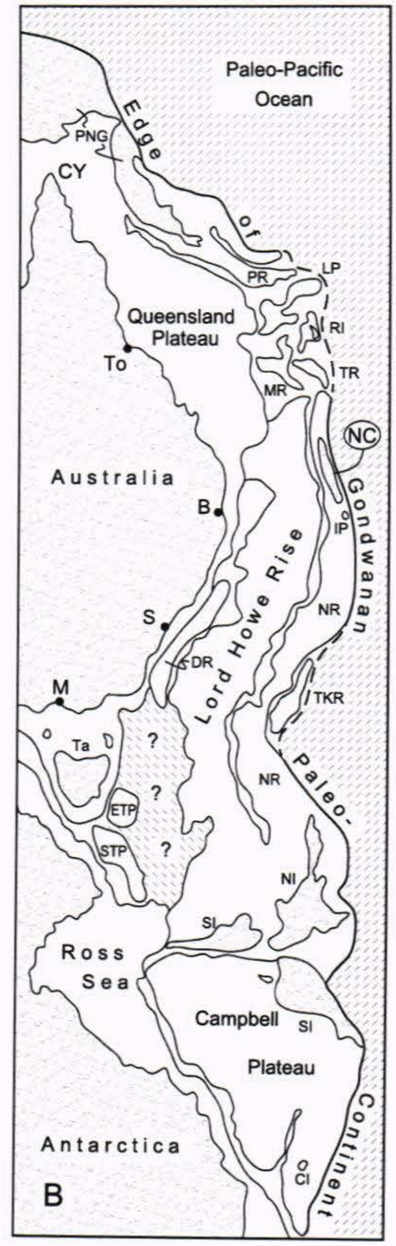

FIGURE 1. Geotectonic framework of southwest Pacific area (NC, New Caledonia): A, current geography; B, reconstructed mid-Cretaceous (~85 Ma) paleogeography.

seafloor basalt representing overlying oceanic crust. The overthrust ultramafic slab of New Caledonia originated as Paleogene forearc basement fronting an intraoceanic island arc of "reversed polarity", analogous to the Neogene island arcs of modern Island Melanesia, and was emplaced by thrusting during attempted subduction of the continental sliver of the Norfolk Ridge downward to the northeast beneath the southwest flank of the island arc. The ancient arc is represented by volcanic underpinnings of the Loyalty Islands, which are now in process of being drawn in turn toward the trench flanking the modern island arc of Vanuatu (Figure 1A). Paleogene overthrusting of ophiolitic rocks above continental underpinnings was not restricted to New Caledonia (Parrot and Dugas 1980; Kroenke 1984), but propagated from mid-Eocene time along the Papuan Peninsula (Davies and Jaque 1984), down the length of the Norfolk Ridge (Figure 1A) past New Caledonia later in Eocene time (Cluzel *et al.* 2001), and ultimately to New Zealand where the Northland ophiolite was emplaced in Oligocene time (Malpas *et al.* 1992).

BEDROCK ASSEMBLAGES

The geologic complexity of the New Caledonian microcontinent can be resolved for interpretations of temper provenance into five main bedrock assemblages (Figure 2) expected to yield different kinds of sedimentary detritus in the form of temper sand. The oldest assemblages are dominantly sedimentary strata formed within a Mesozoic (Triassic-Jurassic) subduction system active along the Gondwanan margin before Cretaceous breakup and drift. Two parallel belts of related Gondwanan orogenic strata are analogous, respectively, to the western marginal and eastern axial facies of New Zealand (Dickinson 1971a), providing evidence for continuity of pre-Cretaceous orogenic trends down the length of the Norfolk Ridge (Figure 1A): (1) a discontinuous belt of pre-Cretaceous forearc strata, the Koumac(NW)-Bourail(SE) sedimentary terrane, is exposed along the southwest coast where not masked along a central segment of the coast by overthrust ophiolitic rocks; (2) a continuous belt of pre-Cretaceous subduction complex, the Central Chain terrane composed of deformed graywacke, and structurally interleaved seafloor igneous rocks (Meffre *et al.* 1996), is exposed mainly along the central mountain chain of the island interior but extends to a central segment of the northeast coast. The Koumac-Bourail and Central Chain terranes can be expected to yield dominantly quartzose detritus including reworked quartz (and minor feldspar) grains intermingled with variable proportions of polycrystalline lithic grains of shale, chert, argillite or slate, and varied volcanic rocks. Both are locally overlain unconformably by Cretaceous strata deposited during or after drift of

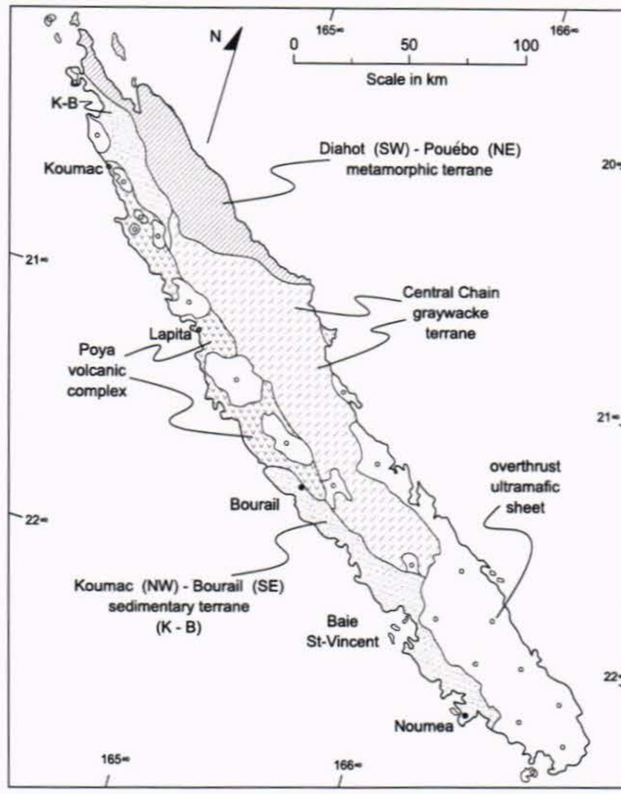

FIGURE 2. Distribution of main bedrock assemblages on New Caledonia (Grande Terre) after Aitchison *et al.* (1995), Brothers and Lillie (1988), Cluzel *et al.* (1994, 2001), Guillon (1974), Lillie and Brothers (1970) and Paris (1981). Circled dots are key Lapita sites.

crustal slivers away from Australia, and by sedimentary rocks deposited during the early phases of Paleogene subduction and overthrusting (Cluzel *et al.* 2001). These sedimentary packets were derived largely, however, from erosion of the subjacent Koumac-Bourail and Central Chain terranes, and should accordingly deliver similar detritus to modern sediment.

At the northwest end of the northeast coast, the foliated Diahot (SW)-Pouébo (NE) metamorphic terrane was formed in Paleogene time through metamorphism of Central Chain and younger subduction complexes beneath overthrust ophiolitic rocks, since removed by erosion. Derivative detritus, otherwise similar in quartzose character to Koumac-Bourail and Central Chain detritus, is expected to include lithic fragments of metamorphic rock (slate or phyllite, schist, quartzite). Some of the metamorphic rocks contain unusual high-pressure/low-temperature (HiP/LoT) heavy minerals (glaucophane, lawsonite, pumpellyite, stilpnomelane) diagnostic of the blueschist metamorphic facies. The presence of such distinctive minerals in New Caledonian temper sands can be taken provisionally as evidence for derivation from the Diahot River drainage or other nearby catchments of northwestern New Caledonia.

Along a central segment of the southwest coast, exposures of the basaltic Poya volcanic complex (Cluzel *et al.* 1997; Eissen *et al.* 1998) occupy an intermediate thrust sheet emplaced above pre-Cretaceous basement but beneath the overthrust ophiolitic slab of mantle peridotite. Metamorphosed counterparts are present within the subthrust Pouébo metamorphic terrane of northeastern New Caledonia (Cluzel *et al.* 2001). As remnant klippen of the structurally overlying ultramafic rocks are present at intervals along the belt of Poya outcrops (Figure 2), derivative sediment is expected to contain mixed mafic and ultramafic detritus composed of both mineral grains (olivine, pyroxene, plagioclase) and lithic fragments (basalt, diorite-gabbro, serpentinite). Along the northeast coast of southeast New Caledonia, and extending into the interior, an overthrust sheet of peridotite and serpentinite forming the highest structural levels on New Caledonia can be expected to yield dominantly ultramafic detritus, which is known to include semi-opaque chrome-spinel (Galipaud 1990). Intrusive granitic bodies enclosed within the ultramafic mass (Guillon 1975; Paris 1981) may contribute minor quartz grains to the dominantly ophiolitic detritus.

TEMPER TYPES

The broad range of temper types in prehistoric New Caledonian potsherds is indicated by the varied temper sands present in 16 sherds from the site at Lapita (Figure 2), 12 sherds from other sites on the Grande Terre, 11 sherds from Ile de Pins, and 11 sherds from the Loyalty Islands. As the Loyalty Islands are raised carbonate platforms, tectonic highland tempers in all the Loyalty sherds indicate ceramic transfer from the Grande Terre (Huntley *et al.* 1983). Other archaeological evidence for prehistoric ties between the Loyalty Islands and the Grande Terre is abundant (Sand 1998, 2001). Quartzose or quartzose-ophiolitic tempers in seven Lapita and non-Lapita sherds from Ile des Pins, composed exclusively of uplifted limestone terraces flanking a central core of ultramafic rock, are positive evidence as well for ceramic transfer from the Grande Terre. Given the prominent raised reef complex that rims Ile des Pins (Paris 1981), ophiolitic tempers in the other four sherds from Ile des Pins probably also reflect ceramic transfer from the Grande Terre.

Four sherds found in Vanuatu containing tectonic highland tempers unlike the volcanic sand tempers of indigenous Vanuatu wares are likewise interpreted to reflect prehistoric ceramic transfer from New Caledonia. A Lapita sherd from Malo contains spinel-bearing New Caledonian temper of mixed ophiolitic-quartzose type (Dickinson, 1971b). An undecorated sherd from Erromango, found on the surface but possibly reworked from a buried Lapita horizon, contains typical quartzose New Caledonian temper (Dickinson, 2001). Two surface sherds of indeterminate age from Santo contain quartz-rich New Caledonian temper sands.

New Caledonian tempers are mineralogically heterogeneous sands (Appendix 1) imbedded in silty clay bodies. In a majority of the sherds, contrasts in grain size between temper grains and the coarsest aplastic particles within clay pastes indicate manual addition of temper, by ancient potters, to sand-free or sand-poor clay bodies. In approximately a quarter of the sherds, however, including half those with significant amounts of ophiolitic detritus in the temper, gradations in grain size between sand temper and finer grained aplastic constituents of the clay pastes imply that ancient potters may have used poorly sorted alluvial clay bodies naturally tempered with sandy detritus. In some cases, manually added temper of coarse sand may have augmented finer grained natural sand temper. Admixtures of calcareous grains of reef detritus show that some tempers are beach sands, but only one-sixth of the tempers contain any calcareous grains. Generally poor sorting and minimal rounding by abrasion suggest that many others are stream sands. Mineralogical criteria for different geologic source rocks of the sand tempers are applicable regardless of sedimentological variability, or whether natural temper or manually added temper is present.

Quartzose tempers (n=20) include aggregates reflecting mixture of mineral grains and lithic fragments (Appendix 1:A) in widely varying proportions. Only the four tempers with highest ratios of quartz mineral grains to quartzose lithic fragments contain characteristic blueschist minerals (glaucophane, lawsonite, pumpellyite, stilpnomelane), either as mineral grains or within metasedimentary lithic fragments, or both. Ophiolitic tempers (n=10) display analogous wide variations in the proportions of different grain types (Appendix 1:B), and many observed tempers (n=12) represent mingling, again in variable proportions, of quartzose and ophiolitic detritus. The terrigenous fractions (silicate-oxide mineral grains and lithic fragments) of eight hybrid temper sands (mixtures of terrigenous-calcareous components) in which calcareous grains of modern reef detritus are dominant represent quartzose (n=2), ophiolitic (n=2), and combined quartzose-ophiolitic (n=4) detritus. The compositional variety of observed tempers documents that mixtures of all end-member types of New Caledonian temper sand (quartzose, ophiolitic, calcareous) occur within the limited suite of sherds examined petrographically. The joint occurrence of both quartzose and ophiolitic components in an individual temper sand is perhaps the most robust signal, apart from blueschist mineralogy in selected sherds, of temper origin from New Caledonia.

TEMPER DISTRIBUTION

The occurrence of different temper types in the sherd suite examined for this study is largely unsystematic (Appendix 2). With respect to bedrock sources (Figure 2), the quartzose tempers tap the sub-thrust sedimentary and metamorphic terranes, whereas the ophiolitic tempers tap the overthrust terranes (Poya volcanic complex and the ultramafic sheet). Unfortunately, approximately half the c.50 local rivers and streams of New Caledonia drain both types of provenance along their short courses from interior highlands down to adjacent coastal beaches, making correlation of temper type with specific geographic locale a severe challenge. Dozens of known archaeological sites distributed around the coast of the Grande Terre (Galipaud 1996; Sand 1999) occur within or near the mouths of drainages tapping virtually every type of geologic provenance, or combination of provenances, on the island.

The advantage for temper analysis provided by small islands that serve as virtual point sources of sand (Dickinson 1998; Dickinson and Shutler 2000), derived from a limited range of bedrock sources, is lost for a landmass as large as New Caledonia (375 km long). In voluminous sherd collections from Koumac and Lapita (Figure 2), for example, both quartz-rich (*quartzose*) and spinel-bearing (*ophiolitic*), as well as calcareous, tempers are present (Galipaud 1990). From the respective locations of the two sites it is unclear, however, whether the varied tempers reflect some level of ceramic transfer from distant sites or simply the presence of multiple temper types available from sand deposits located not far away. At many sites, both types of temper sand, or related intermediate tempers of combined quartzose-ophiolitic character, are apt to occur in streams or on beaches nearby. Calcareous sand is doubtless widespread as potential temper sand on many shorelines, but provides no indication of locale of origin.

Exclusively quartzose tempers lacking HiP/LoT metamorphic minerals are predicted only along short central segments of the northeast coast, where the Central Chain terrane is exposed from the spine of the island down to the sea (Figure 2), and on the southwest coast where detritus from the Koumac-Bourail and Central Chain terranes should be uncontaminated by ophiolitic detritus from either the Poya volcanic complex or the ultramafic sheet (Figure 2). Quartzose tempers from the northwest end of the northeast coast should in principle be distinguishable from other quartzose tempers by the presence of HiP/LoT blueschist minerals in association with abundant metamorphic lithic fragments. This criterion can be successful, however, only if those diagnostic minerals, despite being subordinate constituents of parent metamorphic rock, are actually present in derivative sandy detritus. Exclusively ophiolitic tempers are expected only near the southeast end of the northeast coast of the Grande Terre. The observed distribution of diverse temper types in the sherd suite examined is compatible with considerable ceramic transfer within the Grande Terre during prehistoric times, but no inferences of specific patterns of ceramic transfer can be made with any confidence from the available data. Of special note, however, is the observation that essentially all temper types are present in sherds from the site at Lapita.

SUMMARY CONCLUSIONS

The quartzose-ophiolitic (tectonic highland) temper suite of New Caledonia is readily distinguishable from the volcanic sand and related tempers of other southwest Pacific island groups. Broad geological similarities over wide areas of New Caledonia frustrate, however, any facile petrographic distinction among New Caledonian tempers from different locales on the Grande Terre. Successful correlation of temper type with geographic location might be achieved by detailed investigation of different sherd collections supplemented by study of the various local sands available as potential temper. Even this approach faces the difficulty, however, that modern sand accumulations may differ in both texture and composition from aggregates that were present from place to place in the past. Studies of ceramic typology may offer more efficacious means to assess ceramic transfer, internal to the Grande Terre, than temper analysis. Temper petrography that is efficient for assessing temper suites from smaller Pacific islands cannot be applied without inherent ambiguity to a landmass as large as New Caledonia.

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APPENDIX 1: GRAIN TYPES IN NEW CALEDONIAN TEMPER SANDS

(*mineral* grains are both monomineralllic and monocrystalline, *aggregate* grains are monomineralllic but polycrystalline, *lithic* grains are polymineralllic and polycrystalline)

A. Quartzose tempers

1. Mineral grains: biotite flakes (black mica), epidote (rare), quartz (dominant), feldspar (dominantly plagioclase), opaques (mainly magnetite)

2. Aggregate grains: chert or metachert (microcrystalline chalcedonic quartz), granular epidote, metaquartzite (foliated internal fabric of oriented quartz crystals), polycrystalline quartz (quartzite or vein quartz)

3. Lithic grains: argillite (murky in brownish hues), felsite (volcanic rock fragments with mosaic to microlitic internal textures), slate-phyllite (quartz-mica tectonite with foliated internal fabric)

4. Blueschist detritus (present as monomineralllic grains or within polycrystalline lithic fragments in tempers of Appendix 2:A1 together with dominant quartz grains and subordinate plagioclase grains): actinolite (pale green amphibole), amphibolite (foliated), blueschist (tectonite with glaucophane, lawsonite, pumpellyite, and/or stilpnomelane), garnet, glaucophane (pleochroic blue soda-amphibole), lawsonite, muscovite or phengite flakes (white mica), pumpellyite

B. Ophiolitic tempers

1. Mineral grains: clinopyroxene, olivine, orthopyroxene, plagioclase feldspar, opaques (mainly magnetite), quartz (minor), spinel (the ruby red variety termed chrome-spinel, which is isotropic and translucent rather than transparent in thin section)

2. Lithic grains: basalt (intergranular to intersertal internal textures), basaltic glass (cryptocrystalline in brownish to reddish hues), gabbro-diorite (internal crystals of plagioclase and pyriboles), granitic (internal crystals of quartz and feldspar), peridotite (internal crystals of olivine and pyroxenes), serpentinite

APPENDIX 2: TEMPER TYPES IN SELECTED NEW CALEDONIAN SHERDS

(see Appendix 1 for summary of grain types; numbered sites after Gifford and Shutler 1956)

A. Quartzose tempers

1. Monocrystalline quartz mineral grains dominant over polycrystalline (aggregate plus lithic) grains with diagnostic blueschist minerals present (n=4): three Lapita sherds (8-8, 8-9, 10-1) from Site 13 (Lapita); one Lapita sherd (7-6) from Vatcha (Ile des Pins); minor admixtures of calcareous grains in all but one sherd (10-1).

2. Monocrystalline quartz mineral grains and polycrystalline (aggregate plus lithic) grains approximately equal in abundance (n=6): three non-Lapita sherds (8-3, 9-2, 9-5) from Site 13 (Lapita); one sherd (11-5) from Site 36 near Bourail; two sherds (30-1, 30-3) from Wano-Wattom.

3. Polycrystalline (aggregate plus lithic) grains dominant over monocrystalline quartz grains (n=10): four non-Lapita sherds (8-1, 8-4, 8-5, 9-3) from Site 13 (Lapita); one sherd each from Site 32 (11-1) near the west coast and Site 49 (11-2) on the east coast; four sherds (52-2, 52-3, 52-4, 52-6) from Ouvea (Loyalty Islands).

B. Ophiolitic tempers (n=10): two sherds (6-1, 6-2) from Kapume and one non-Lapita sherd (7-1) from Vatcha on Ile des Pins; two sherds (11-9, 11-10) from Site 40A near Noumea; one sherd from Site 21 (11-13) on Baie St-Vincent; one sherd from Ouvea (52-5) and three sherds (52-10, 52-12, 52-13) from Maré in the Loyalty Islands.

C. Quartzose-ophiolitic tempers composed of mixed quartzose and ophiolitic detritus (n=11): two Lapita sherds (9-7, 10-5) from Site 13 (Lapita); one sherd each from Sites 15A (11-12) and 37 (11-3) near Bourail; two sherds (31-1, 31-4) from Wano-Wattom; two Lapita (7-8, KVO-3-2) and one non-Lapita (7-3) sherd from Vatcha (Ile des Pins); one sherd (52-1) from Ouvea and two sherds (52-8, 52-9) from Maré in the Loyalty Islands.

D. Dominantly calcareous tempers (n=8) with admixtures of quartzose (Q), ophiolitic (O), or quartzose-ophiolitic (Q-O) terrigenous detritus: three Lapita sherds (9-6 with Q, 9-8 with Q-O, 10-3 with O) and one non-Lapita sherd (9-8 with Q-O) from Site 13 (Lapita); four Lapita sherds (KVO-3-4 with Q, 7-9 with O, KVO-3-1 and KVO-3-3 with Q-O) from Vatcha (Ile des Pins).