

Jade occurrence in the Suckling-Dayman massif, eastern Papua

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Abstract: Jade is widely distributed throughout the 2200 km long New Guinea Mobile Belt, associated with numerous tectonised and serpentinitised ultramafic rocks, metabasites and blueschist rocks containing intrusive masses of serpentinite with tectonic inclusions, tremolite rocks and talc. One region in particular, centred on the Suckling–Dayman massif in eastern Papua, is of interest as jade tools including adze and axe blades and lime spatulas and float specimens are present in an extensive 10,000 km² region including Cloudy Bay, Keveri Valley, Ibinambo River, Collingwood Bay, Holincote Bay and Musa River. This paper provides a description of the geological setting of the

Suckling–Dayman massif and the region’s jade occurrences and the potential for a jade industry in Papua New Guinea. Nephrite prospecting and mining is primarily for ‘barefoot prospectors’. It is low technology, not requiring professional skills or specialist and expensive methods such as those used in conventional mineral exploration. With government agency technical assistance and support from NGOs it is possible to establish in Papua New Guinea a network of jade buyers and sellers and a local jade carving industry.

Keywords: eastern Papua; jade; Keveri Fault; Mai’iu Fault; nephrite; serpentinite; Suckling–Dayman massif; talc; tremolite; ultramafic rocks

1. Introduction

Lindley and White [1] first recognised and described the widespread occurrence of jade throughout the 2200 km long New Guinea Mobile Belt, associated with numerous tectonised and serpentinitised ultramafic rocks, metabasites and blueschist rocks containing intrusive masses of serpentinite with tectonic inclusions, tremolite rocks and talc. These occurrences are not unexpected given the similarities of the geological setting of New Guinea jade occurrences with other jade provinces. Jade mineralisation occurs when stop-start slip along large faults results in localised and transient P – T conditions with relatively low temperatures (ranging from ~100–200°C to ~300–350°C) and high pressures (<200–500 Mpa). One region in particular, centred on the Suckling–Dayman massif in eastern Papua, is of interest as jade tools including adze and axe blades and lime spatulas and float specimens are present in an extensive 10,000 km² region including Cloudy Bay, Keveri Valley, Ibinambo River, Collingwood Bay, Holincote Bay and Musa River (Figure 1). This paper provides a description of the geological setting of the Suckling–Dayman massif and the region’s jade occurrences and the potential for a jade industry in Papua New Guinea.

2. Geological setting of the Suckling–Dayman massif

2.1. Regional setting

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The Suckling–Dayman massif is located at the eastern end of the New Guinea Mobile Belt (Figure 1). The belt runs the length of the New Guinea Cordillera and consists of a complex system of great faults with vertical displacements of up to 8000 m. The belt separates folded platform sequences underlain by crystalline rocks of the Australian Plate to the south and oceanic crust and island arcs to the north and northeast. Lindley and White [1] described jade found at numerous localities within the mobile belt in extensive linear belts of tectonised and serpentinitised ultramafic rocks and metabasites, blueschist rocks, intrusive masses of serpentinite, tremolitised rocks and talc.

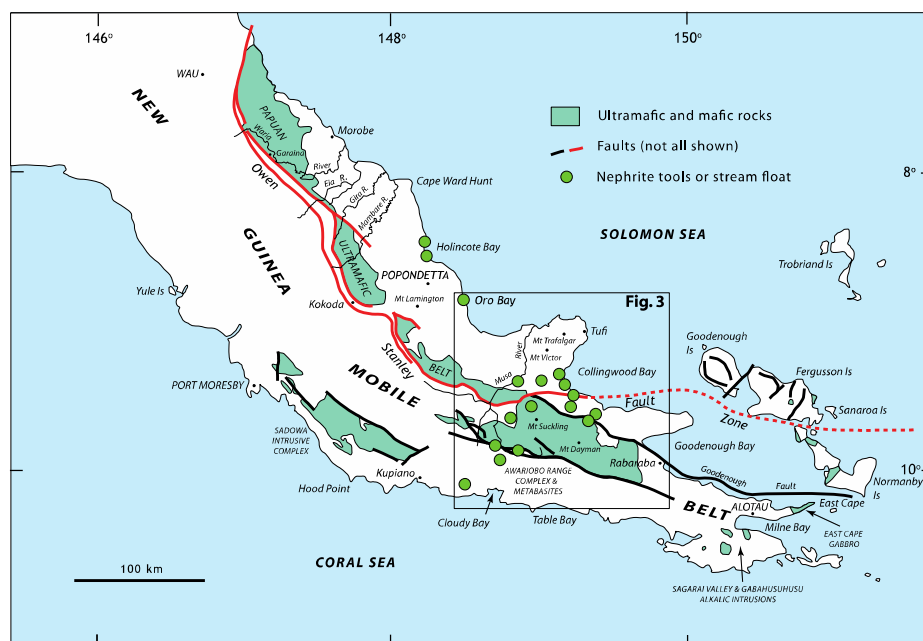


Figure 1. Map of eastern Papua showing occurrences of nephrite tools, serpentinite and tremolite, mafic and ultramafic rocks, ophiolites and major faults in the Suckling–Dayman massif, New Guinea Mobile Belt. The trace of the Owen Stanley Fault and Keveri Fault after Lindley [2].

2.2. The Suckling–Dayman massif: Buoyancy-driven uplift or uplift associated with folding of a subduction zone

The Suckling–Dayman massif consists of two actively rising domes known as the Suckling Dome and Dayman Dome [3, 4, 2]. Contrasting degrees of stream dissection indicate that the Suckling Dome is an older structure than the Dayman Dome [2, 5]. The massif to the north is bounded by the Mai'iu Fault, a fast-slipping low-angle (30°–40°) normal fault (Figures 2 and 3) [6]. Movement along this fault has resulted in the exhumation of the core of the Dayman Dome from depths of 20–30 km. To the south, the massif is bounded by the Keveri Fault, a high-angle fault that has accommodated large vertical movements (Figures 2 and 3) [2]. Lindley calculated that the fault accommodated 8000 m of uplift during the past 5 Ma, at an average rate of uplift of 2.5 m/10³ a. Recent inversion modelling of total magnetic intensity data acquired along the length of the Keveri Fault indicates it is vertical to at least 7–10 km depth [2]. There are two schools of thought on the origin of these dome structures.

The model of buoyancy-driven uplift of the Dayman Dome was proposed by Ollier and Pain in 1980 and 1981 [7, 8]. Lindley concluded that this model adequately accounted for the geology and tectonic history of the Suckling Dome [2]. An obvious gravity low is present under the Suckling–Dayman massif [9] and Davies and Warren [10] considered it may be related to felsic material below the metabasite carapace of the domes. Granite and monzonite stocks crop out on the summit of the 3676 m high Mt Suckling. These felsic rocks are likely the tops of larger bodies at depth that contributed to the uplift of the massif, beginning in the late Miocene [2].

Uplift of the Suckling–Dayman massif associated with folding of a subduction zone was proposed by Davies in 1978 [4] and 1980 [11]. Daczko *et al.* [3], who worked on the Mai’iu Fault and the Dayman Dome, wrote: ‘However, no evidence of this thrust was observed in shear zones examined in this study...This study also contradicts Davies (1980), wherein he concludes that convergent tectonics were the prime mechanism for elevating and folding the metabasites into the broad dome landform.’ Davies’ model has been the subject of much recent research by Little *et al.* [5] and others [6, 12], mainly focussed on the Mai’iu Fault and the Dayman Dome, and they concluded ‘Our data support the model’. They considered the deformation

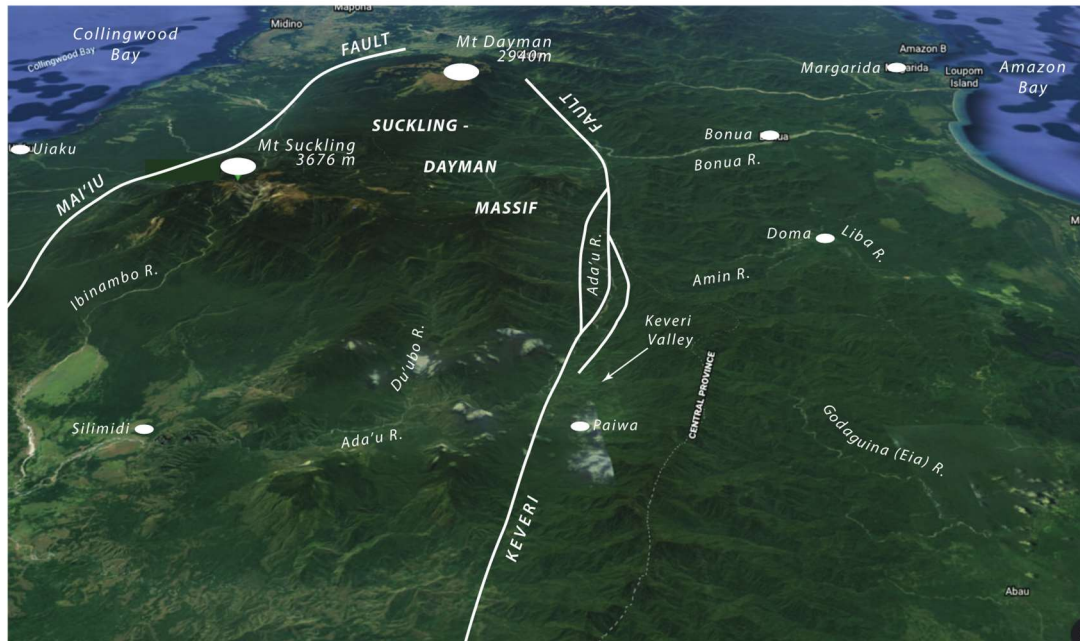


Figure 2. An oblique view of the Suckling–Dayman massif on the Papuan Peninsula. The image shows the Mai’iu Fault and the Keveri Fault, bounding structures to the massif. Viewed looking east. Base map: Google maps, 2022.

of the Suckling–Dayman massif as indicative of rolling-hinge–style deformation [5]. Little *et al.* [5] stated that compelling evidence for this style of deformation is ‘The deformed, convex-up shape of the exhumed fault surface (of Mt Dayman), the southeastern part of which dips to the south.’ This geomorphological feature can be explained by buoyancy–driven uplift.

2.3. Discussion

It is not the subject of this paper to argue the pros and cons of each model. However, with the senior authors’ extensive fieldwork in the Mt Suckling area, it is worthwhile pointing out some geological inconsistencies with recent work. The geology of the Ada’u and Keveri Valleys to the north and south of the Keveri Fault is relatively simple and sedimentary units (Ada’u Limestone, Domara River Conglomerate) are typically flat-lying with little or no deformation, except drag-induced tilting adjacent the Keveri Fault. This is not the geology expected of a folded subduction zone, as proposed in the rolling-hinge–style deformation model. Lindley argued that gravity and geological evidence suggests the Owen Stanley Fault, the basal contact of the ophiolite Papuan Ultramafic Belt (PUB) and a thrust surface, and an integral component of the rolling-hinge–style deformation model, passes well to the north of the Suckling–Dayman massif (Figure 1) [2]. Little *et al.* [5] considered that ‘The exposed Owen-Stanley fault (*sic.*) is crosscut by several small plugs of Suckling Granite...and by a larger stock of Mai’iu Monzonite.’ This is incorrect as the fault has not been mapped across the summit of Mt Suckling [13].

Lindley's [2] detailed mapping in the Ada'u Valley, presented at 1:50 000 scale, does not indicate the presence of a layered PUB sequence. Detailed low-level airborne geophysics (magnetics and radiometrics) commissioned by the senior author in 2010, and supplemented with ground traversing, has proven a useful tool in tracing the boundaries of the variously magnetic geological units in this rugged area. A large area is underlain by late Oligocene-middle Miocene pillow basalt lava. Basalt/limestone breccias in Urua Creek were dated using foraminifera [2]. Lindley [2] used PGE geochemistry, the absence of a sheeted dyke complex, the absence of a metamorphic sole, the lack of a prominent positive gravity anomaly (typically associated with the PUB) and the presence of distinctive chromitite-bearing dunite in the Ada'u Valley, unique in eastern Papua (H.L. Davies, *pers. comm.* 1990), to show that the mafic and ultramafic sequence in the Mt Suckling region is not an ophiolite and part of the PUB. Lindley erected a new formational name, the Awariobo Range Complex, for these rocks. The complex is interpreted to have formed in a magmatic arc [2].

The absence of the late Cretaceous–middle Eocene Kutu Volcanics (it should be present at the top of the PUB sequence) in the Suckling–Dayman massif is problematic. The senior author has not mapped pillow basalts similar to the Kutu Volcanics, which he has observed elsewhere in eastern Papua, including the Waria Valley, Sagarai Valley, Milne Bay Goldfield and Dawadawa River. The relatively common gabbro dykes found in the formation are not found in the pillow basalts north or south of the Keveri Fault. As with Davies and Smith [9], Little *et al.* [5] appear to have dismissed palaeontological evidence on the age of limestone clasts contained in the pillow basalt lavas that is not compatible with a Kutu Volcanics age. Little *et al.* [5] dismissed these data in preference for only late Cretaceous–middle Eocene ages, in-line with the PUB model. They wrote: 'To the NW of Mount Suckling, the Kutu volcanics (Davies and Smith, 1974; but called the Wavera volcanics by Lindley, 2014) are interbedded with limestones that contain foraminifera of mostly Eocene, but locally late Oligocene to early Miocene, age.' Clearly, Little *et al.* [5] mean exposures in the Ada'u Valley, well to the south of Mt Suckling. The basalts of the Wavera Volcanics often contain breccias with clasts of limestone, and foraminifera from previously collected samples in the Bureau of Mineral Resources' collection and samples provided by the senior author were examined by G. Chaproniere. He determined a late Oligocene–Middle Miocene age. These young volcanics form a mappable unit in accord with stratigraphic guidelines. Lindley's 1:50 000 geological map [2] shows the widespread occurrence of the basalt/limestone breccias. Biostratigraphic work has indicated the Wavera Volcanics is coeval with the Ada'u Limestone [2]. The two units have intermingled.

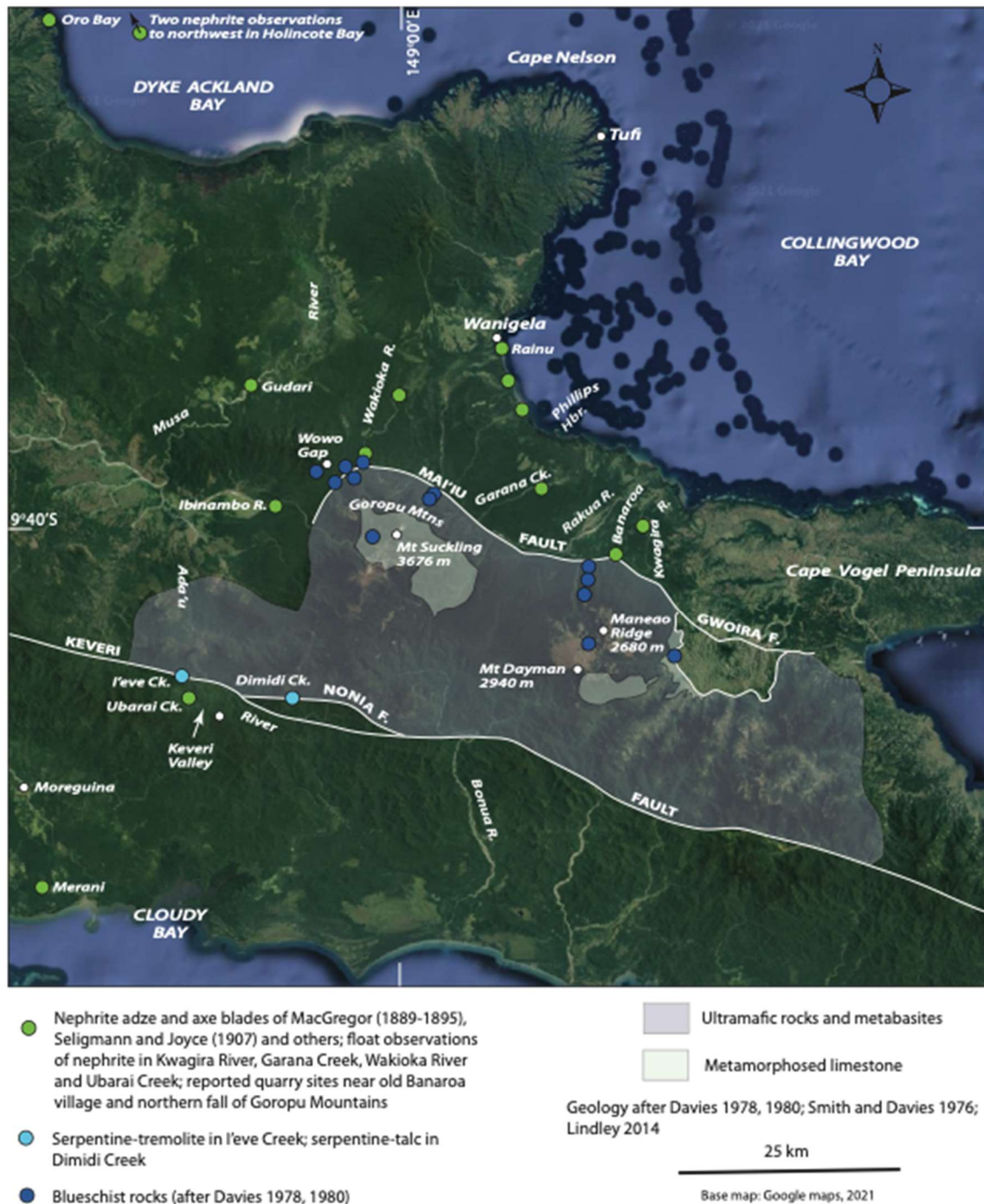


Figure 3. Regional geological map of Suckling–Dayman massif, showing major faults, ultramafic rocks and metabasites, calcareous schists, occurrences of blueschist rocks and the location of nephrite adze and axe blades from the observations of William MacGregor, Administrator of British New Guinea, between 1889-1895 and C.G. Seligmann and T.A. Joyce in 1906. Geology and distribution of blueschist rocks after Davies. Trace of the Gwoira Fault after Webber *et al.* [6]. The trace of the Keveri Fault and Nonia Fault after Lindley [2].

3. Description of jade from eastern Papua

Many of the jade tools from eastern Papua were collected by William MacGregor between 1888-1898, while he was Administrator of British New Guinea (BNG). MacGregor's 'Official' collection, amounting to 10,959 objects, is now dispersed around the world including Queensland Museum, Papua New Guinea National Museum and Art Gallery, Australian Museum, Museums Victoria and the British Museum [14]. Objects from his 'Personal' collection were deposited in university museums including the

University of Aberdeen, University of Cambridge and Oxford University [14]. During our present work jade tools deposited in the British Museum were studied. A total of 721 objects from MacGregor's 'Official' collection, including these jade tools, were deposited with the British Museum [14]. Two jade tools from C.G. Seligmann and T.A. Joyce's 1906 fieldwork in Collingwood Bay are also deposited in the British Museum and were inspected [15]. Other jade objects relevant to our study were sourced from private collections. The reader is referred to Lindley and White [1] for a listing of all BNG administration reports relevant to jade occurrences in eastern Papua.

3.1. Collingwood Bay-Holincote Bay jade axe and adze blades

Collingwood Bay is located north of Mt Suckling and Mt Dayman (Figure 3). Streams rising on the northern flanks of the massif intersect the bounding Mai'iu Fault. MacGregor collected jade tools during his visit to villages west of Phillips Harbour in Collingwood Bay, Oro Bay and towards Holincote Bay in July–August 1890 (Figure 3) [1]. He noted that use of jade blades begins to be mixed with adzes of basalt towards the northwest and Holincote Bay [1]. Subsequent BNG Administration expeditions in 1891 and 1894 were focussed on locating the source of jade collected by MacGregor on the northern slopes of Mt Suckling and Mt Dayman, respectively [1]. Nephrite was seen as a mineral resource of potentially considerable value for the struggling British New Guinea. These expeditions located float of jade in Garana (Dori) Creek and Kwagira River, respectively (Figure 3). It was during the latter expedition that party leader R.E. Guise was advised by villagers that jade was obtained near (the now abandoned) Banaroa village, lying under the foot of Maneáo Range (Figure 3).

Jade tools collected by MacGregor and deposited in the British Museum were examined by the senior author in May 2023 (Figure 4). They are typically dark green, tough, have a sub-vitreous lustre, are obviously translucent along thin edges and have a relatively high specific gravity. R.L. Jack, Government Geologist, Queensland, studied some of the Collingwood Bay blades in 1892 and noted that the nephrite had a fibrous texture and was intergrown with serpentine [1]. One of the blades (BM Oc,MCG.197; Figures 4e, f), 8.7 cm in length, has rough surfaces indicating it is little worked. It is gently curved from end to end. Clearly, it was likely formed in a fault zone.

Two green adze blades were collected by Seligmann and Joyce in 1906 from coastal Rainu village, 3 km east of present day Wanigela village [15]. They were originally determined to be ophicalcite, and were examined by the senior author at the British Museum in May 2023 and are without doubt nephrite (Figure 5). Seligmann and Joyce noted that the stone was quarried on the northern fall of the Goropu Mountains and was traded down the Wakioki (Wakioka) River and Musa River [15]. Egloff completed extensive archaeological excavations in the same area near Wanigela, commencing in November 1967, and although his work yielded numerous fragments of ground stone tools, none of them were nephrite [16].

Several jade objects from Collingwood Bay and contained in private collections do not have precise locations. A small nephrite blade (Figure 6a) is of a similar colour and lustre to the MacGregor blades. A large, rounded stream float measuring 15 cm x 5.5 cm (widest part) x 4 cm, contains anastomosing veins of nephrite up to 10 mm thick in a sheared rock (Figure 6b). The nephrite is tough and shows a greater resistance to stream transport than the host rock. A betel stained lime spatula (Figure 6c) is tapered at one end and in profile is gently curved from end to end. The spatula measures 20.5 cm x 0.5 cm x 3.0 cm (rounded end) and is the longest piece of nephrite known from eastern Papua. The nephrite is dark green, translucent and tough. As with the similarly curved MacGregor blade BM Oc,MCG.197 (Figure 4f) it is good evidence for origin in a fault zone.

3.2. Musa River jade axes

MacGregor subsequently observed jade axes in Gudari village in the upper Musa River during a tour of inspection completed in 1895 [1]. Gudari is located downstream of

the Didana Range (Figure 3). Information from villagers corroborated Guise's information that nephrite was traded from the Maneáo Range.

3.3. Ibinambo River, Safia district, jade report

British New Guinea patrol officer C.A.W. Monckton, with Captain F.R. Barton, during his patrol in search of Doriri murderers in April 1901 provided a very clear description comparable with Collingwood Bay jade [17]. At a village on the Ibinambo River, on the western flanks of Mt Suckling (Figures 1, 2 and 3), Monckton described 'cleverly split slabs of green jade from the hills of Collingwood Bay, which they used for making stone heads for disc clubs, tomahawks or adzes.' His location information was undoubtedly obtained from villager informants. The Ibinambo River intersects the westernmost extensions of the Mai'iu Fault (Figure 3).



Figure 4. Collingwood Bay nephrite blades collected by William MacGregor in 1890. The MacGregor collection is deposited with the British Museum: (a) Damaged adze blade, broken at tapered end. Broken end has weak tremolite. Rock is perhaps a semi-nephrite, 9.8 cm x 8.0 cm x 2.1 cm, BM Oc,MCG.196; (b) Axe blade, 7.5 cm x 4.5 cm x 1.5 cm, BM Oc,MCG.201; (c) Adze blade, 6.0 cm x 4.6 cm x 1.0 cm, BM Oc,MCG.198; (d) Blade, 12.2 cm x 7.0 cm x 1.7 cm length, BM Oc,MCG.57; (e, f) Little worked adze blade with rough surfaces, 8.7 cm x 3.7 cm x 0.7 cm, BM Oc,MCG.197. This thin 0.7 cm (maximum) wide blade is gently curved from end to end and was likely quarried from a fault zone.

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Figure 5. Collingwood Bay adze blades collected from excavations at Rainu village by C.G. Seligmann and T.A. Joyce in 1906. The Seligmann and Joyce collection is deposited with the British Museum: (a) Adze blade, 11.7 cm x 4.0 cm x 5.0 cm, BM Oc,1906.1014.2. A thin and flat blade, with an irregular oblong outline; (b) Adze blade, 4.5 cm x 4.5 cm x 1.2 cm, BM Oc,1906.1014.3. Both blades are of dark green, tough and dense nephrite.

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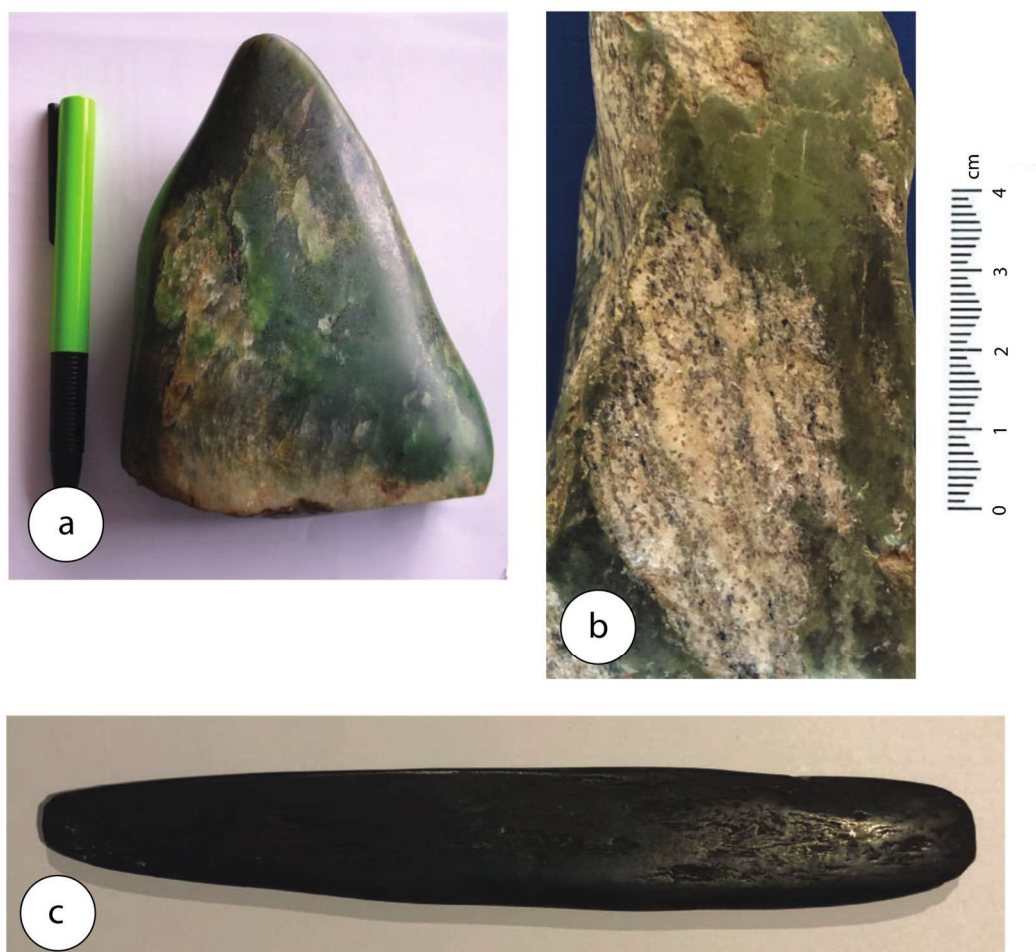


Figure 6. Collingwood Bay nephrite objects from private collections. (a) A small nephrite blade, of a similar colour and lustre to the MacGregor blades; (b) A large, rounded stream float measuring 15.0 cm x 5.5 cm (widest part) x 4.0 cm, containing anastomosing veins of nephrite up to 10 mm thick in a sheared rock. The nephrite is tough and shows a greater resistance to stream transport than the host rock; (c) A lime spatula, betel and lime stained, is tapered at one end and in profile is gently curved from end to end. The spatula measures 20.5 cm x 0.5 cm x 3.0 cm (rounded end) and is the longest known piece of nephrite from eastern Papua. The nephrite is dark green, translucent and tough. As with the similarly curved MacGregor blade BM Oc,MCG.197 (Figures 4e, f) it is good evidence for origin in a fault zone. .

3.4. I' eve Creek tremolitised boulders and Ubarai Creek nephrite blade, western Keveri Valley

Large tremolitised boulders consisting of yellowish serpentine with tremolite are present in I' eve Creek near its confluence with Wavera River at the western end of the Keveri Valley (Figures 2 and 3). Tremolite occurs as foliated masses consisting of long, slender dark grey crystals to 5 cm length (Figure 7a). I' eve Creek is a west-east flowing stream within the trace of the Keveri Fault. Country rock in the I' eve catchment consists of tectonised peridotite and pyroxenite of the Awariobo Range Complex, faulted against basalt and pelitic schists and phyllites of the Owen Stanley Metamorphics [2]. The nearby occurrence of a nephrite blade in Ubarai Creek, at old Paiwa village and only 1000 m from I' eve Creek, may suggest local sourcing of this jade (Figure 3). The patchy pale green and whitish nephrite is distinctive for an obvious strong shearing with inclusions of tremolite and talc (Figure 7b), suggesting sourcing from the Keveri Fault.



Figure 7. I'eve Creek tremolitised boulders and Ubarai Creek nephrite blade: (a) Tremolite from a large boulder of yellowish serpentine-tremolite in I'eve Creek, western Keveri Valley. The creek follows the trace of the Keveri Fault; (b) Patchy pale green and white nephrite axe blade from Ubarai Creek, Paiwa village, western Keveri Valley. The blade is tough and dense, and sheared areas have inclusions of tremolite and talc. The blade is 15.2 cm x 5.0 cm (at widest point) x 2.5 cm.

3.5. Dimidi Creek serpentinite zone with tectonic inclusions and talc, Ada'u Valley

A 16 m wide serpentinite zone is exposed in Dimidi Creek, a northern tributary of the Ada'u River, rising on the southern fall of Mt Suckling (Figures 2 and 3). The zone includes a large tectonic inclusion of weakly serpentinised pyroxenite and talc (Figures 8a, b). Country consists of serpentinised peridotite. Outcrop flanking the zone is poor and broad alluvial flats, in this otherwise extremely steep terrain, may be underlain by sheared, talcose rocks. The Dimidi Creek zone is located within the Nonia Fault, an east-west splay of the parallel Keveri Fault [2]. The fault is likely to have accommodated large vertical movements, possibly during a period of locking along a section of the nearby Keveri Fault [2]. As with the Mai'iu Fault, it is likely that stop-start slip occurred along the fault.



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Figure 8. Dimidi Creek serpentinite zone with tectonic inclusions and talc: (a) Tectonic inclusion of brittle serpentinised peridotite within the 16 m wide Dimidi Creek serpentinite-talc zone, Ada'u Valley. The zone is in the Nonia Fault; (b) Talc alteration in the Dimidi Creek serpentinite zone.

3.6. Cloudy Bay nephrite blades collected by William MacGregor

Axe blades of jade were first observed by William MacGregor in eastern Papua in October 1889 at Merani village, during a visit of inspection to the Cloudy Bay district (Figures 1 and 3). Two axe blades (Figures 9a , b) were inspected by the senior author during a visit to the British Museum in May 2023. The blades are relatively small, with lengths ranging from 6.7 cm to 10.0 cm. They each consist of a dark green tough nephrite, with a sub-vitreous lustre and a relatively high specific gravity.



Figure 9. Cloudy Bay nephrite blades collected by William MacGregor in 1889. The MacGregor collection is deposited with the British Museum: (a) Blade bound into wood holder with bush rope, 10.0 cm x 4.5 cm x 1.4 cm, BM Oc,MCG.53; (b) Blade bound into wood holder with bush rope, 6.7 cm x 2.8 cm x 0.7 cm, BM Oc,MCG.55.

4. A jade industry in Papua New Guinea?

Jade is highly marketable, with uses as jewellery and ornamental stone. It has long been used and is especially popular in China, Taiwan, Siberia, Canada, New Zealand and other countries. The Suckling–Dayman massif provides multiple jade targets. It is very rugged and remote. Mai'iu Fault targets in the Goropu Mountains are particularly rugged and difficult to access from Collingwood Bay (Figure 2). Targets along the front of the Maneáo Range are easier to access. Some of the broad Keveri Fault runs the length of the braided Ada'u River, with splays such as the Nonia Fault in rugged terrain. Rugged terrain is present along the trace of the Keveri Fault east and west of the Ada'u Valley. The Ada'u Valley can be easily accessed by a 3-day trek along the Babauguina track, linking Cloudy Bay with Paiwa village [18].

Nephrite prospecting is primarily for 'barefoot prospectors'. It is low technology, not requiring professional skills or specialist and expensive methods such as those used in conventional mineral exploration, e.g. geochemical analysis. Prospectors need to be aware that the outer skin or 'rind' covering a jade boulder is deceiving. Appraisal of any large boulders of nephrite requires drilling or sawing with portable saws to identify their worth. The use of explosives will induce fractures and the damaged jade is unattractive to the carving industry [19]. Jade is appraised by the appearance of the sawn faces or drill cores through the rock. Colour is the most important parameter. Bright 'lively' green is the most highly prized, but there is a demand for dark green or black material, and mottled colours may be acceptable for carving grades.

Four grades are commonly used [19]. Premium Grade A material is free of fractures and inclusions of other minerals and be highly translucent. Grade B jade is of good colour in most of the material, has few fractures or inclusions and is used in the carving industry. Grade C material is of inferior colour, with numerous fractures or inclusions, and is not

suitable for high-grade jewellery. It is where variegation is acceptable. Grade D material is non-commercial, where the cost of extraction from the mine site does not justify processing. At some localities, such as the Cassiar pit in British Columbia, boulders are sold as rough and untested, without saw cuts or core holes. This is convenient for the miners, but it obviously means the buyers take a chance.

Jade mining is a relatively inexpensive operation, and because of this many small operators have worked jade areas in countries including China, New Zealand and Canada [19]. Once a stockpile of sawn blocks amounts to a few tonnes, it is possible to fly production out by helicopter to the nearest road or port [19]. Supporting infrastructure will quickly follow, encouraged by government agency technical assistance and perhaps support from NGOs in establishing a network of jade buyers and sellers and a local jade carving industry. Assistance in all aspects of the industry, from prospecting to carving, may come from New Zealand, where there is a well-established jade carving industry. Māori carvers will be helpful in developing a distinctive Papua New Guinean style of carving.

5. Conclusions

1. Two rock types are encompassed by the term jade: nephrite, a mainly tremolite-ferro-actinolite rock and jadeitite, a rock consisting mainly of jadeite. Only nephrite is present in eastern Papua.

2. The distribution of nephrite tool occurrences and tremolite and talc rocks indicates that jade mineralisation is sourced from the Suckling-Dayman massif. The unique localised and transient P - T conditions required for nephrite formation are provided by the bounding faults to the massif, the Mai'iu Fault and Keveri Fault. The entire length of these structures is prospective for nephrite.

3. Villager reports at the time of early contact with Europeans indicate nephrite quarry sites were located in the Wakioka River headwaters in the Goropu Mountains and in the vicinity of old Banaroa village at the foot of the Maneáo Range.

4. Nephrite prospecting and mining is primarily for 'barefoot prospectors'. It is low technology, not requiring professional skills or specialist and expensive methods such as those used in conventional mineral exploration.

5. With government agency technical assistance and support from NGOs it is possible to establish in Papua New Guinea a network of jade buyers and sellers and a local jade carving industry.

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Conflicts of Interest: The authors declare no conflict of interest.

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