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Obsidian sources and distribution systems in Island Southeast Asia: a review of previous research

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A B S T R A C T

This paper summarises research on obsidian findings across the region of Island Southeast Asia (ISEA), from the first reporting of obsidian on Sumatra as a result of cave excavations in the early 1900s through to the latest published discoveries in 2009. These results are the background for the first region-wide research project focussing on obsidian characterisation and its role in prehistoric inter-island exchange. It is commonly held that distribution of obsidian in ISEA was only localised and inter-island transportation limited. The review, however, suggests that this hypothesis derives from an incomplete knowledge of obsidian distribution in the region rather than typifying prehistoric social patterns. Obsidian sourcing has been carried out only intermittently in ISEA since the 1970s and has generally been focussed only at the single site level, thus explaining this very partial understanding.

1. Introduction

Migration and exchange between islands have been dominant themes in the archaeology of Island Southeast Asia (Bellwood, 1997; Bulbeck, 2008). The spread of the Austronesian language family throughout Island Southeast Asia (ISEA) and further into the Pacific has captured the interest of a variety of scientific disciplines including linguistics, genetics, botanical science and environmental studies in addition to archaeology (Donohue and Denham, 2010). The debate over population migration versus other forms of cultural transmission of early Neolithic culture within ISEA relates to a broader discourse in island archaeology about driving forces of cultural change (Anderson, 2006; Boomert and Bright, 2007; Spriggs, 2008). Are seascapes and resultant distances between islands factors that isolate communities from each other (Bellwood, 1978, 1996) or do they facilitate interrelations between seafaring groups (Gosden and Pavlides, 1994)?.

Archaeological science is well situated to contribute significantly to this discourse. Here, we present the archaeological record of a pristine raw material with the potential to answer questions about migration and exchange between communities: obsidian. We concentrate on obsidian exploitation and transportation because its complex genesis, the discrete distribution of its sources and the comparative ease of geochemical analysis make it possible to track social interaction through space and time.

The initial report of seaborne transport of obsidian in the wider region is contained in one of the German missionary Otto Meyer's early reports on his discovery of what came to be known as Lapita pottery on Watom Island, off the coast of East New Britain in the Bismarck Archipelago (Meyer, 1910, translation in Anson, 1998:18–20). A later pioneering sourcing study showed the obsidian to originate from over 250 kms to the west in the Talasea area of New Britain (Key, 1968). In 1908, at the same time as Meyer was investigating pottery and obsidian on Watom, the Swiss geologist August Tobler was reporting obsidian artefacts from the

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cave excavation of Ulu Tianko on Sumatra in present-day Indonesia (cited in Sarasin, 1914). Between the World Wars there was an expansion of archaeological research across ISEA and a major obsidian 'microlithic' industry was reported from the Bandung area of West Java, initially by de Jongh in 1930 and soon followed by other researchers discussed by Bandi (1951) and on Luzon and Panay in the Philippines by Beyer, although publication was held up until after World War II (1947). The first chemical sourcing of obsidian artefacts from both the Western Pacific and Indonesia took place during the 1970s. Although individual artefacts and occasional source obsidians from Indonesia were included in some early studies (Bird et al., 1981, Smith et al., 1977), the results were not enlightening in terms of sea transport of obsidian until the spectacular results obtained from Bellwood and Koon's (1989) excavations at Bukit Tengkorak in Sabah, Borneo. The site was contemporary with Lapita sites in the Western Pacific, and obsidian sourcing using PIXE-PIGME showed that some of the obsidian had been transported from West New Britain in the Bismarck Archipelago. This demonstrated obsidian movement at approximately 3000 cal BP over a straight-line distance of over 3500 km.

In this paper, we review the geology of the region as background to the archaeological investigations of obsidian finds and obsidian sources. These are then detailed island-by-island across ISEA. We close with a summary of knowledge and prospects on the eve of the first region-wide research project focussing on obsidian characterisation and its role in prehistoric inter-island exchange (see Reepmeyer et al., this volume).

2. Background: geology

The orogeny of Island Southeast Asia is a complex system of arc-continent collisions at the intersection of the Indo-Australian, Eurasian and Pacific tectonic plates (Hall, 2002). The region's geology can be attributed to tectonic motions of a range of microplates that result in a highly active seismic and volcanic province. It is the most active volcanic region on earth, with more than 150 active volcanic centres (Sendjaja et al., 2009).

The dominant geomorphological features of the region are situated at the continental margin of the Sunda Shelf (Fig. 1). The Sunda Mountain System and the circum-Sunda Mountain system derive from subduction processes of the Indo-Australian tectonic plate under the Eurasian Plate in the south and southwest and the subduction of oceanic plates (including the Pacific Plate, the Philippine Sea Plate and the Caroline Plate) under the Eurasian Plate in the northeast of the study area (Hall, 2002). The subduction processes originate from converging plate boundaries and feed volcanism along the Sunda Arc, including the islands of Sumatra and Java, and along the complex Philippines' Arc systems of the region, including the Moluccas (Hall, 2002, van Bemmelen, 1970). The island of Sulawesi and associated smaller islands derive from subducting microscale plate tectonic processes along the southern margin of the Celebes Sea Plate and the Moluccas Sea Plate resulting in active volcanism in the area (Hall, 2002; Hutchison, 2005). The Banda Arc in the southeast of the study area is situated on the continental margin of the Sunda Shelf and has a particularly complex orogeny. The Banda Arc is separated into an inner volcanic arc, the subduction zone of the Australian plate, and an outer non-volcanic arc, which accreted in the Neogene to the Sunda shelf moving at the same rate as the Australian Plate (Elburg et al., 2005). The Outer Banda Arc was formed in the Permian to Quaternary ages and consists mainly of metamorphic and sedimentary rocks, with only a few igneous facies (Hall, 2002). Island uplift on the Outer Banda Arc in the terminal Pliocene and Pleistocene is associated with folding processes of the continental shelf rather than active volcanism (Richardson and Blundell, 1996).

Quaternary volcanism of arc systems can be found along the Sunda-Banda Arc, at the southeastern margin of the Celebes sea and along the Philippine Arc system (Sendjaja et al., 2009:203, Fig. 1). In the case of the Sunda Arc the Quaternary volcanics overlie typical igneous and associated sedimentary fossil arcs of late Palaeozoic age at the western end through to those of Tertiary age in the east. Fossil arcs in the Philippines have similar ages in general as their late Mesozoic counterparts to the south, the majority formed during Jurassic to Cretaceous times (Corby et al., 1951, van Bemmelen, 1970:227–229).

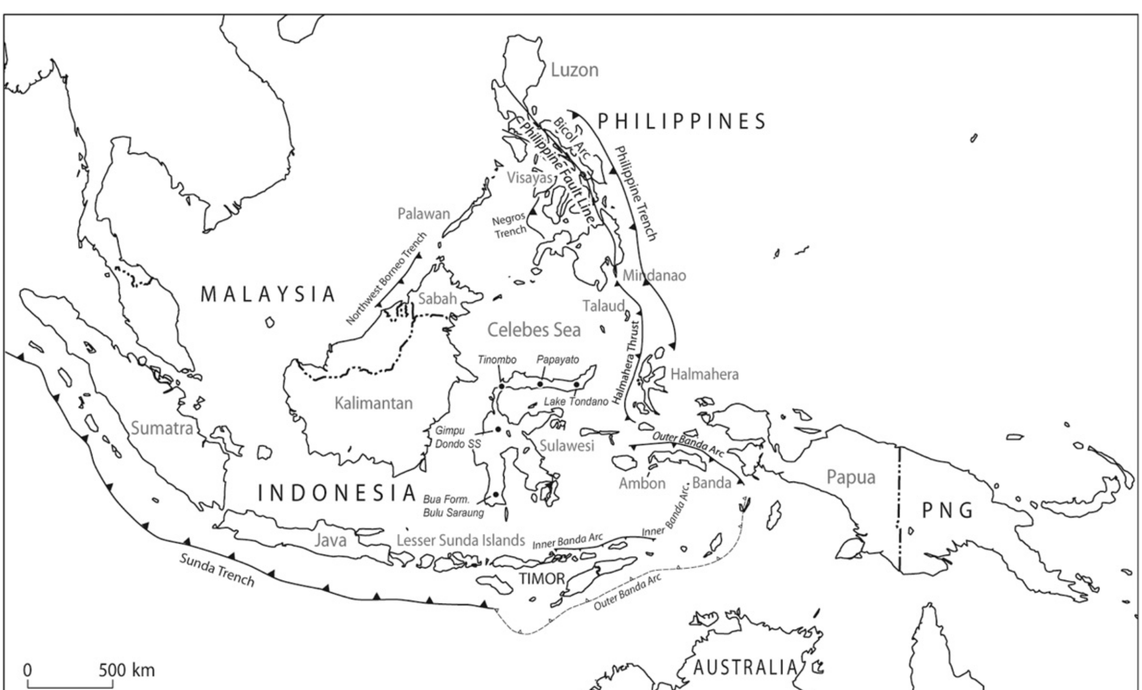

Fig. 1. Location of geological features mentioned in the text.

The orogeny of igneous suites in the study area associated with converging oceanic and continental tectonic plates results in an island-arc pattern of the geochemical distribution of surface rocks on the Sunda-Banda Arc, the south Celebes Sea Arcs and the Philippine Arcs. In general, island-arcs are characterised by a wide array of SiO_2, enriched Al_2O_3 and depleted TiO_2, Na_2O and MgO contents (Albarède, 2003). Geochemical research in the study area shows evidence of rhyolitic and dacitic facies at several locations in the Sunda-Banda Arc. Besides the well-known and well-researched rhyolitic volcanism on Sumatra and West Java (Sendjaja et al., 2009), locations in the Lesser Sunda Islands can be found with potential for obsidian genesis, particularly Bali, central Flores and Lombok (Wheller et al., 1987).

The volcanic islands of Wetar and Alor on the western Banda Arc, dormant during the mid to late Pleistocene, consist mainly of rhyolitic and dacitic formations (Elburg et al., 2002a). Further eastwards, additional locations of felsic formations occur along the Banda Arc: (1) in the Banda Islands (Whitford et al., 1977) and particularly the southeastern section, the islands of Maupura and Romang (Honthaas et al., 1999), and (2) at the northernmost end of the Banda Arc, the Ambon segment, in which Jezek and Hutchison (1978:591) described an obsidian-crust outcropping in one location on Ambon. All of the suites on the Banda Arc are characterised by extremely enriched trace elements and radiogenic Sr–Pb isotopes (Vroon et al., 1995).

Associated with the South China Sea and the Northwest Borneo trench tectonic movements, Cenozoic volcanism in the northern interior of Sarawak on the island of Borneo produced Oligocene to Miocene aged dacites, rhyodacite tuffs and glassy lavas and later Miocene to Pleistocene aged dacites and andesites (Hutchison, 1996, 2005, Soeria-Atmadja et al., 1999).

On Sulawesi, the occurrence of obsidian outcrops in Minahasa around Lake Tondano has been discussed by Bellwood (1976) and Ambrose et al. (2009). However, the occurrence of possible obsidian outcrops on Sulawesi might not be limited to the northeastern section of the island. Elburg et al. (2003:244, Fig. 1) described high-silicate volcanics associated with the Papayato and Tinombo formations extending to the west, with the Dondo Super Suite and Gimpu volcanics (Polvé et al., 1997) in western and central Sulawesi and the Bua Formation in southern Sulawesi (Elburg et al., 2002b). Archaeological research (see below) in southwestern Sulawesi noted a possible obsidian source around Bulu Saraung (formerly Piek van Maros); however, no detailed geochemistry is available for this potential source and its relation to other volcanic suites is unknown at this stage.

The islands to the east of Sulawesi, associated with arc–arc collision around the Moluccas Sea Plate are primarily of Quaternary age (Macpherson et al., 2003). Ambrose et al. (2009) reported the geochemistry of a single flake from a secondary deposit (G. Hope, pers. comm.) of high-silicate obsidian on Tidore, off Halmahera, which correlates well with the presence of acidic glass on the Halmahera Arc (Hakim and Hall, 1991; Morris et al., 1983). Moore et al. (1981:472) also described a high-silicate brown glass matrix on the islands of the Talaud group.

Geochemical research on the complex Philippine island arc system provides insight into the wide array of possible high-silicate Quaternary volcanics in the region with the potential for obsidian genesis (Faustino et al., 2003, Yumul et al., 2008). Rhyolitic and dacitic formations in the Philippines associated with medium to high Potassium values are found in the Bataan Segment and the Macolod Corridor on the southern Luzon Arc, central Luzon (Defant et al., 1989:666–667, Fig. 3, Förster et al., 1990). At the southernmost end of Luzon active Quaternary volcanism along the Philippine trench, particularly associated with the Philippine fault line, produces rhyolitic formations of the Bulusan volcanic complex on the Bicol Arc (McDermott et al., 2005). Further west, Quaternary volcanics in the Visayas related to subduction processes along the Negros Trench (Barrier et al., 1991) produce adakites on Negros island (Bellon and Yumul, 2001). Finally, further south along the Philippine trench and the Philippine fault, Quaternary volcanics on Mindanao display typical island arc high-silicate and medium-rich calc-alkaline andesites and dacites (Sajona et al., 1993).

This brief, selective overview has concentrated on Quaternary volcanism as obsidian devitrifies over time so that it is assumed that surface findings of pre-Neogene workable obsidian outcrops only exist on rare occasions (Khalidi et al., 2010:2336). The

Fig. 2. Location of archaeological sites and obsidian sources mentioned in the text.

overview of potential high-silicate rhyolitic and dacitic locations suggests that many more obsidian locations in the ISEA might yet be uncovered.

3. Background: locations

3.1. The Philippines

3.1.1. Luzon

In a recent publication on Philippine obsidian sources and artefacts, Neri (2007) has summarised current knowledge about obsidian sources and artefact distribution in the Philippines. His own study - the first geochemical analysis of Philippine obsidian artefacts - involved XRF and PIXE-PIGME analyses of artefacts from the Huluga open site in northern Mindanao (Neri, 2003). He compared them with known sources in the Western Pacific, Java and two sources on Luzon: Nagcarlan and Pagudpod (Fig. 2). The Nagcarlan source is located in Laguna Province in the south of Luzon and Pagudpod is a pitchstone source in Ilocos Norte Province near the northwest end of the island (Neri, 2003).

The Nagcarlan and Pagudpod locations remain to this day the only confirmed geological obsidian and pitchstone sources in the Philippine archipelago. Obsidian artefacts have been found throughout Laguna Province as well as in several other archaeological sites at some distance from either of these sources (Neri, 2007:154–156). Neri lists finds by Beyer (1947), Paterno (1981) and Ronquillo and Ogawa (1996) in Rizal, Cavite, Batangas and Bulacan Provinces in southern Luzon. Beyer (1947:215, 250) examined further obsidian artefacts from Laguna, also in the south, and a single small flake from Ilocos Norte. He considered that the Luzon obsidians came from both Neolithic and Pre-Neolithic contexts. De la Torre (1997; 2002) and Bautista (1995) reported obsidian artefacts from the site of Ulilang Bundoc in Calatagan, Batangas Province, where they were associated with earthenware secondary burial jars in Metal Age contexts (i.e. dating to after 2100 cal BP). Seven obsidians from this site were sourced by Neri (2007) using XRF to the Nagcarlan source, 60–70 km to the northeast. Scott (1984:13) refers to obsidian artefacts being recovered around Mount Taal, and an earlier publication of his (Scott, 1968) reports additional finds of obsidian from the Bicol region in the extreme southeast of Luzon.

Another reference to obsidian in Luzon is from Pintu shelter in Nueva Vizcaya, which is not far from the central east coast (Peterson, 1974). Peterson (1974:28) states that “obsidian are also represented in small amounts”, although he classifies obsidian wrongly as ‘cryptocrystalline’, along with flint, chert and chalcedony. He does not report whether the obsidian was from Neolithic or underlying Pre-Neolithic levels. Additional obsidian artefacts were found in the Irigayen (Santa Maria) site, Cagayan Province in northern Luzon, where Ogawa (1998:147–148) reported obsidian flakes in a silty clay layer with plain red slip pottery of early Neolithic age. This layer was later dated to between 3446–3371 and 3202–2994 cal BP (Ogawa, 2005:30)[1]. Irigayen is one of a large complex of early Neolithic sites going back to about 3800 cal BP along the Cagayan River and showing clear links with a Taiwanese ’homeland’ (Hung, 2008).

3.1.2. Palawan

Several obsidian artefacts were recovered from Ille cave on Palawan Island in Palawan Province (Paz and Ronquillo, 2004). These were located on the eastern side of the cave close to the drip line at around 180 cm below surface. The occupation history of the site has recently been clarified as dating from the terminal Pleistocene to the mid-Holocene, with a series of 17 AMS dates ranging between c.11000 and 9400 cal BP (Lewis et al., 2008). Quaternary volcanism and associated high-silicate facies do not occur on Palawan Island (Suzuki et al., 2000, Yumul et al., 2009) and so the source of the obsidian artefacts must be off-island.

3.1.3. Panay, Cebu and Mindoro

Beyer (1947) reported a much-worn obsidian artefact of unknown age from the Tigbauan site in Ilolio Province on the island of Panay. Obsidian artefacts have been found at several locations on the island of Cebu in the central Philippines. Tenazas (1985) found an industry of small obsidian flakes in Pre-Neolithic levels at the Tagotong Hill Site, and Neri (2007:156) lists further recent finds (discussed further in Reepmeyer et al., this volume). Mijares (1996:34) reported recovering surface finds of weathered obsidian flakes at Tinokod Cave in Mindoro Occidental Province on Mindoro Island.

3.1.4. Mindanao

Obsidian artefacts were found on Mindanao in two sites near Kibawe in Bukidnon Province to the southeast which yielded materials of Neolithic and later periods (Neri, 2007:156). A second location with obsidian was reported from the Bungiao rock shelter in Zamboanga Province in easternmost Mindanao. This site was excavated by Spoehr (1973:243), who found seven obsidian flakes in a probable Neolithic context, although the site was disturbed by later activities.

In the last decade, Neri et al. (2005) and colleagues have excavated several sites in the northern part of Mindanao, including the open site of Huluga near Cagayan de Oro City believed to be of Neolithic age. Their research also covered several other sites in the vicinity of Huluga, all of which produced obsidian artefacts in some quantity (Neri, 2007). Neri was unsuccessful in matching the Mindanao artefacts to the known sources in the Philippines. However, based on the trace element distribution of the artefacts he proposed that the origin was unlikely to be in the Mindanao area itself and suggested an extra-archipelagic source.

3.1.5. Sanga Sanga

Finally, Spoehr (1973:259) recovered a single piece of obsidian from Neolithic levels of the Balobok Rock shelter on Sanga Sanga Island, Tawi Tawi Province, towards the western end of the Sulu archipelago very close to Sabah. This proved to be very much an isolated find as no additional obsidian was found during extensive re-excavation of the site in the early 1990s (Ronquillo et al., 1993).

3.2. Malaysia

3.2.1. Sabah/Borneo

Test excavations in 1987 conducted by Bellwood and Koon (1989, see also Bellwood, 1989) in the north Borneo rock shelter and open site complex of Bukit Tengkorak in the Semporna region of Sabah recovered a quantity of obsidian. Subsequent geochemical analysis of the excavated obsidian artefacts using PIXE-PIGME resulted in the first identification of West New Britain obsidian in ISEA. Other obsidians from the site matched a single piece found earlier by Bellwood in the Talaud Islands (Bellwood and Koon, 1989). These preliminary investigations of the site were followed by several excavations by Chia (2003b) and a major obsidian sourcing project by Tykot and Chia (1997, also Chia, 2003a, 2003b). Of the 552 artefacts uncovered in the later excavations 30 were selected for analysis by electron microprobe and WDXA. The preliminary provenancing of artefacts in Bellwood and Koon’s study (1989) to the Kutau/Bao source in West New Britain and

[1] Radiocarbon dates available in the literature have been recalculated for this study from the original data using CALIB 6.01 (Stuiver et al., 2011), calibration using IntCal09 and Marine09 (Reimer et al., 2009).

a second unknown source matching samples found in the Talaud Islands in eastern Indonesia was confirmed. Additionally, one sample was tentatively sourced to the Admiralty Islands, possibly originating from one of the Lou Island sources (Chia, 2003a:55).

The artefacts sourced to West New Britain were with two exceptions, possibly displaced, found in Neolithic layers starting at the earliest at 3315–2951 cal BP and 3186–2892 cal BP and continuing to at least 2968–2463 cal BP (cf. Chia, 2003b). An earlier Pre-Neolithic occupation starts at 6281–5939 cal BP (Chia, 2003b, cf. Spriggs, 2003:61). The majority of the obsidian artefacts found in this older occupation layer match the sample from Talaud (Chia, 2003a:57). The single Admiralty Island obsidian piece was found in Neolithic levels (Tykot and Chia, 1997). During later fieldwork seasons in the Semporna region in 2002–2007 two additional rock shelter sites, Melanta Tutup and Bukit Kamiri, were excavated, containing obsidian artefacts associated with red-slipped pottery of Neolithic age (Chia, 2005, 2008). Geochemical characterisation of the obsidian artefacts is pending.

3.3. Indonesia

3.3.1. Talaud

A single obsidian artefact was found from Neolithic levels at the Leang Tuwo Mane'e excavation on Karakellang in the Talaud Islands (Bellwood, 1976:261). This piece was included in the Bird et al. (1981) PIXE-PIGME study of obsidian sources in the Pacific and Southeast Asia but could not be ascribed to a source. As previously noted, Bellwood and Koon (1989) confirmed by Tykot and Chia (1997) reported a match of the geochemical composition of this artefact with obsidian artefacts now known to come predominantly from Pre-Neolithic levels at Bukit Tengkorak. Tanudirjo's (2001) re-excavation of the Leang Tuwo Mane'e site added a further piece of obsidian to the inventory. As with the piece found by Bellwood (1976), this was found in Neolithic levels, which are now thought to begin at the site around 3808–3433 cal BP (Spriggs, 2003).

3.3.2. Sulawesi

Bellwood (1975) found several obsidian artefacts in the lower levels of the Paso shell mound in northern Sulawesi on the shore of Lake Tondano, Minahasa, during excavations in 1974. The detailed description of the Paso site by Bellwood (1976:243–254) dated the layers containing obsidian to 9442–7567 cal BP and 8915-7590 cal BP. There are also Neolithic deposits at the site but it was not clear to the excavator whether the use of obsidian carried on into this period. Smith et al. (1977:186) noted that these artefacts were different macroscopically from the Sumatran and Javanese obsidians. Bellwood (1975:34) suggested that this "prolific flake industry" was of local origin as several possible sources exist, particularly on the northwestern side of Lake Tondano.

Tanudirjo (2001) returned to northeast Sulawesi in the 1990s and reported an obsidian outcrop in the village of Tataaran to the northwest of Lake Tondano, suggesting this as the source for the artefacts excavated by Bellwood earlier at the Paso shell midden some 20 km away. He also found a surface scatter of obsidian in the nearby village of Timu but excavation of the site revealed only modern materials there (Tanudirjo, 2001:148). Ambrose et al. (2009) included one piece from this area in their recent LA-ICPMS analysis of East Timor obsidians.

In central Sulawesi, the Kamassi site, located 90 km inland of the west coast, along the Karama River and 1 km downstream of Kalumpang, has received archaeological attention on several occasions (Simanjuntak et al., 2008:59, Fig. 6.3). Thirty-two "unworked" obsidian flakes were reported as surface finds by van Heekeren (1972:182–189) during excavations of Neolithic deposits in 1949 on the surface of a flat summit of the southern part of the Kamassi Hill, along with some fragments of porcelain. During subsequent archaeological investigations in 2008, Simanjuntak and his team excavated a trench of 4.5 m $\times$ 1.5 m on the north slope of the Kamassi hill (Prasetyo, 2008). They uncovered a 150 cm thick cultural layer containing 68 obsidian flakes. The obsidian appeared in the middle to the upper habitation layer but was absent in the oldest layer (Tim Penelitian, 2008). The flakes were found in association with red-slipped pottery, plain and decorated sherds. These layers were dated to 3206–2363 cal BP (Geolabs-411: 2700 $\pm$ 150 BP: Simanjuntak, unpublished data).

Archaeological surveys at the nearby Minanga Sipakko site (Simanjuntak, 1994-1995:21, Simanjuntak et al., 2008) yielded a single surface-collected flake. This may post-date Neolithic occupation at the site which has radiocarbon determinations of 3063–2788 cal BP at 155–160 cm below surface. This flake was characterised using PIXE-PIGME (Bird, 1996). A second flake, recovered in excavation at the Metal Age Sabbang Loang site on the bight due east of Kamassi was found by Summerhayes to be from the same unknown source and was in a layer dated to 2336–1635 cal BP (cited in Bulbeck and Prasetyo, 2000:124–125, date recalibrated). These latter authors conclude that the obsidian at Kamassi, Minanga Sippako and Sabbang Loang dates to no earlier than the latest Neolithic or Early Metal Age just over 2000 years ago. It certainly postdates any Neolithic habitation levels at the latter two sites.

From the many caves sites in southwest Sulawesi (Bartstra, 1998), the only obsidian reported in print is a single piece from Leang Lampoa near Maros, excavated by Franssen in 1948 (Franssen, 1949). There are both Pre-Neolithic and later deposits at this site but the stratigraphic allocation of the piece is unknown (Bulbeck et al., 2001:82). In association with this obsidian find, Franssen (1949:335) reported a possible obsidian source on the slopes of the Bulu Saraung mountain (Piek van Maros), but no geochemical data are available from this potential source.

In the Australian Museum collections in Sydney, however, three further obsidian specimens from "Maros Caves" in South Sulawesi were accessioned in 1938, donated by von Stein Callenfels[2]. The most likely source of this material is from caves he excavated in 1937. One was excavated in the company of F.D. McCarthy of the Australian Museum and W J A. Willems at Panisi Ta'buttu to the northeast of Maros (van Heekeren, 1972:112–114). The short description by van Heekeren of the material recovered there makes this a possible candidate as the source of the Australian Museum collections. Van Stein Callenfels then excavated two sites on his own at Pangangreang Tudea and Batu Edjaya on the coast south of Maros and these are other possibilities.

3.3.3. Tidore

Ambrose et al. (2009:609) reported the geochemistry of one sample of obsidian surface-collected in 1992 by Geoff Hope of the Australian National University (ANU) on the lower eastern slopes of Mount Kiematubu on Tidore island off the west coast of Halmahera in the Moluccas. The source of this piece is unclear, as no obsidian outcrops have been found on any of the northern Moluccan islands. Jezek and Hutchinson (1978:591) reported a glassy crust of pillow basalts on the island of Ambon in the central Moluccas, but the XRF results from this outcrop do not match the elemental composition of the Tidore piece.

3.3.4. Banda Islands

Other recent archaeological finds of obsidian in the Moluccan region include three pieces from the Neolithic open site of PA1 on

[2] They are registered as parts of collections E45003 and E45015; information from Val Attenbrow, personal communication. 10.

Pulau Ay in the Banda archipelago, associated with pottery and pig bone and bracketed by dates on pig bone of 3208–2850 cal BP below and 3825–2879 cal BP above (Lape, 2000a:215–229). The association of this material with a sherd displaying a Lapita-like pottery motif - a style found to the east of New Guinea at this time - is particularly intriguing (see Spriggs, 2011 for discussion, sherd illustrated in Lape, 2000b).

3.3.5. Flores and Lomblen

Verhoeven (1953) reported a microlithic culture at two sites in west and central Flores similar to the one described by Tobler (Sarasin, 1914) on Sumatra. The artefacts are specified as made from shell and 'stone' (Verhoeven, 1953:601), and images suggest the occurrence of obsidian (see also Bellwood, 1978:218). This seems confirmed by van Heekeren (1972:141) who remarks on the Pre-Neolithic site of Liang Toge in Western Flores: "Special mention must be made of the absence of obsidian as used in other caves on Flores". In van Heekeren's (1972:146) own excavation of Liang Rundung in north-central Flores, again predominantly Pre-Neolithic in age, he notes the presence of obsidian among the raw materials (see also Smith et al., 1977:186). Obsidian flakes were collected in the hills inland from Lewoleba on the small island of Lomblem just to the east of Flores by Verhoeven in 1961 in association with other artefacts of chalcedony and jasper (Liong, 1965), but no further details are available.

3.3.6. Java

For western Java, the microlithic obsidian industry was first noted by the geologist A.C. de Jongh in 1930, and investigated by him and the archaeologist von Koenigswald over the next few years (von Koenigswald, 1935). Bandi (1951) summarised the 1930s and 1940s research by these scholars and by Krebs, Franssen and Rothpletz in the area and described the collected findings as an elaborate hunter-gatherer small flake industry (based on European terminology he called this industry 'mesolithic'). Later research reported by Sutayasa (1979) in the Bandung and Bogor areas (the latter some 175 km west of Bandung) suggested that these industries were established in the late Pleistocene and continued into Neolithic times (also van Heekeren, 1972:133–137, McKinnon, 2002). As later undisturbed assemblages are missing, it was unclear whether the occurrence of obsidian artefacts in "Palaeometallic" contexts (Sutayasa, 1979:73) is evidence for a continued use of flaked obsidian artefacts into the first millennium AD.

XRF analysis of the geochemistry of a single obsidian artefact suggested a source near Leles as the possible provenance (Subagus, 1979, analysis in Smith et al., 1977). The Leles or, rather, Nagrek or Nagreg source is associated with the Kiamis rhyolite lava dome on the slopes of the Gunung Kendang volcanic complex some 50 km southeast of Bandung; near the town of Garut (Chia et al., 2008). Source samples from here have been analysed with XRF by Smith et al. (1977), PIXE-PIGME by Bird et al. (1981) and LA-ICPMS by Ambrose et al. (2009). Chia et al. (2008) compared Nagrek and a nearby source at Kampung Rejeng, part of the same volcanic complex, using EDXA and Electron Microprobe, finding them to be chemically indistinguishable. They also characterised obsidian artefacts from levels dating to 9500–5600 cal BP in Gua Pawon cave, to the northwest of Bandung. These turned out to be from these Garut-area sources. On the other hand, surface-collected finds from Dago and Bukit Karsamanik near Bandung came from sources yet to be determined. Additional sources of obsidian are associated with the domes of Gunung Halu and Jampang (Sukabumi), to the southwest and west of the Bandung area respectively (Chia et al., 2008).

In addition, there may be a separate source of obsidian in eastern Java, where at Sodong rock shelter, near the south coast to the east of Puger, van Heekeren (1972:103) excavated 67 stone flakes including obsidian from Pre-Neolithic levels. It is notable that in the Gunung Sewu region to the west of Puger (but still in eastern Java) extensive recent excavations have not yielded any obsidian (Simanjuntak, 2002).

3.3.7. Sumatra

Sites with obsidian artefacts have been found in the four southernmost provinces of Sumatra of Lampung, Sumatera Selatan, Jambi and Bengkulu, dating between the Terminal Pleistocene and the later Metal Age. As noted earlier, the first reports of obsidian artefacts in ISEA came from Sumatra, from cave excavations by Tobler and later Zwierzycki in the Upper Jambi (Djambi) District (Sarasin, 1914; Zwierzycki, 1926). Bronson and Asmar (1976:137) reported the occurrence of primary deposits of obsidian most probably originating from a series of volcanoes on the southern shores of Lake Kerintji in the southwestern part of Sumatra. PIXE-PIGME data were obtained from three samples from this source (Bird, 1996). A second source was described by Bronson and Wisseman (1974:88–89) in the middle drainage of the Merangin and Mesumi Rivers, but no elemental data are available. Bronson and Wisseman (1974) also described the occurrence of obsidian artefacts at nine sites in the western Jambi Province, which are assumed to originate from the local Kerintji source.

At Tianko Panjang, first excavated by Zwierzycki and 5 km from Tobler's cave of Ulu Tianko, obsidian was associated both with Neolithic and Pre-Neolithic levels, the latter going back to 12517–11403 cal BP (Bronson and Asmar, 1976:136). At Bukit Batu Larung near Rehahkemumu village in the Serapas area of western Jambi obsidian was found in a village site, associated with porcelain and metal, the earliest date for which was 1221–665 cal BP. Similarly, at Renahkemumu village itself obsidian and pottery were scattered among jar burials, one of which produced a date of 953–552 cal BP (Bonatz et al., 2006). Further south other obsidian finds have been made at several sites: around Lahat in Sumatera Selatan and at Tulang Padangin in Lampung (van der Hoop, 1941:169), and more recently in Neolithic levels at the cave site of Pondok Silabe and at the Neolithic open habitation sites of Gunung Kahuripan and Tapak Harimau, all near the Ogan River in the Baturaja area of Sumatera Selatan (Forestier et al., 2006). At Pondok Silabe obsidian did not occur in Pre-Neolithic levels dating between 5891–4420 and 3444–3224 cal BP but only in Neolithic levels in association with pottery and dated to between 3262–2363 and 1874–1623 cal BP (Simanjuntak et al., 2006). Obsidian is also found at Neolithic jar burial sites in Muara Sepang (Bengkulu), and at Kunduran to the northeast of Pondok Silabe (Bonatz et al., 2006, Simanjuntak and Forestier, 2004:110–115). An association of obsidian with the manufacturing debris of ground and polished Neolithic adzes was found at a workshop site at Lubuk Layang, near Bunga Mas, Sumatera Selatan (Bronson and Wisseman, 1974:88).

3.4. East Timor

Glover (1986) reported obsidian in the form of small pebbles eroding from the edges of volcanic rocks underlying uplifted limestone terraces in Baucau in north-central East Timor. Samples of this source have been recently analysed with LA-ICPMS by Ambrose et al. (2009). The source has been identified as low-silicate pitchstone that was utilised to produce flaked artefacts in the rock shelter sites of Bui Ceri Uato and Bui Ceri Uato Mane dating from around 7500 cal BP onwards. Obsidian artefacts were also reported from three rock shelter sites, Matja Kuru 1 and 2 and Jerimalai, towards the eastern tip of East Timor (Ambrose et al., 2009, Reepmeyer et al., in press) in layers extending back to more than

40,000 years ago. These artefacts were sourced to a single high-silicate source of unknown location.

4. Conclusions

This paper has sought to summarise a very disparate body of material. Many of the reports of obsidian artefacts in ISEA are over 50 years old and from sites not revisited in the interim. Very little geochemical research was undertaken on sources and artefacts until the last decade, and so variability between sources and intra-source variability have been barely understood. The distribution of artefacts themselves when occurring in any number has suggested likely locations of sources in the islands on which they occur: Luzon, Cebu, north and central-south Sulawesi, Flores, West Java South Sumatra and possibly also Mindoro in the Philippines, East Java, Borneo and East Timor.

Obsidian has been reported from Palawan but the geology there is definitive against local origins for these finds. Mindanao has in the past been claimed as not being likely to produce obsidian sources either, but our survey of the geological literature suggests that a source may well one day be found there. Occasional finds on other islands such as Panay, Sanga Sanga and the Talaud group (the artefacts at the latter sharing an origin with some from Sabah) suggest off-island sources for these finds, but only a single piece among them from Talaud has been subject to geochemical analysis.

The overall picture for ISEA is thus one of multiple sources, most of which have never been geochemically analysed. There is definitive evidence of inter-island transport of obsidian in the shared source of artefacts from Talaud and Sabah on Borneo, and for extremely long-distance transport in the case of the West New Britain and Admiralties obsidian found in Neolithic deposits on Sabah. The finding of occasional flakes of obsidian on some other islands may also intimate inter-island transport, and the geology of Palawan strongly suggests that all finds of obsidian on this island will have an extra-local source.

The review of the geology of ISEA and the long history of archaeological research revealed the necessity for a multi-regional and more targeted research effort investigating geochemical variability in obsidian artefacts and source samples. This would provide a more exact idea of the degree of inter-island transport of obsidian during the Late Pleistocene and the Holocene. The wealth of geochemical literature but the lack of detailed geochemical knowledge about obsidian outcrops demanded the application of geochemical techniques to provide accurate and precise measurements of a wide variety of elements, including trace and rare earth elements. For the new study of obsidian artefacts and sources we decided to apply the geochemical method of laser ablation – inductively coupled plasma mass spectrometry (LA-ICPMS) as this technique, albeit minimally destructive, has the proven capability (Speakman and Neff, 2005) to provide accurate results of a wide array of major, minor, trace and rare elements. The results of the new sourcing program are presented in Reepmeyer et al. (this volume).

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