Journal of Archaeological Studies in India

Vol. 2, No. 2, 2022, pp. 101-113

URL: http://arfjournals.com/jasi

https://doi.org/10.47509/JASI.2022.v02i02.04

New Chronometric Dating of Indian Middle/Upper Palaeolithic Sites at Jwalapuram, Andhra Pradesh, Southern India

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Abstract: *Jwalapuram is the archaeological site-complex having large number of localities in the Kurnool district of Andhra Pradesh, southern India. It is a rare Paleolithic site with a stratified record of Middle to Upper Paleolithic transition. Though its archaeological records have markedly contributed to the discussion regarding modern human dispersal into South Asia, there remains ambiguity about its chronology, especially the age of the deposits above tephra from the Toba eruption at ca.74ka (YTT). We dated these deposits above YTT using two different methods, ^{14}C (AMS) and OSL, to confirm their younger age: 30–40 ka. In this paper, we present the detail of the dating, and discuss the implications of the results.*

Keywords: *^{14}C and OSL dating, Jwalapuram sites, Middle to Upper Paleolithic transition, South Asia, YTT*

Received : 11 October 2022
Revised : 15 November 2022
Accepted : 28 November 2022
Published : 27 December 2022

TO CITE THIS ARTICLE:

Taro Funaki, Hiroyuki Sato, Ravi Korisettar, Yorinao Shitaoka, Atsushi Noguchi & Jun'ichi Nagasaki 2022. New Chronometric Dating of Indian Middle/Upper Palaeolithic Sites at Jwalapuram, Andhra Pradesh, Southern India. *Journal of Archaeological Studies in India*, 2: 2, pp. 101-113. *https://doi.org/10.47509/JASI.2022.v02i02.04*

1. Introduction

The timing of modern human dispersal into different areas of the Old World has been one of the most intensely debated issues in many fields, including archaeology, anthropology, and genetics. It is assumed that *Homo sapiens* originated from Africa in 300ka (Hublin *et al.*, 2017; Richter *et al.*, 2017) and then spread to other regions, but the route and timing of arrival into each area is still uncertain. From the late 1980s, rapid development in genetics has contributed to solving the enduring problem regarding the modern human origin (e.g., Multiregional vs. Single African origin) and propose the new model for the subsequent dispersal. One of the models presented by genetics is the "southern dispersal route" hypothesis. This hypothesis claims that the initial dispersal of modern human population from Africa involved the southern part of the Eurasian continent along the route from the African Horn, the Arabian peninsula, Indian subcontinent, and South-Eastern Asia to Eastern Asia/Australia (Stringer, 2000; Oppenheimer, 2009; 2012a; 2012b). In the controversy regarding the southern dispersal model, South Asia, present-day India, Pakistan, Bangladesh, Afghanistan, Nepal, and Sri Lanka were often assumed to be one of the oldest refugia for the initial dispersal population (Endicott *et al.*, 2003; Kivisild *et al.*, 2003; Metspalu *et al.*, 2004; Bae *et al.*, 2017). Thus, the antiquity of the *Homo sapiens* population in this area has been inferred to have significant importance for the overall dispersal discussion.

In contrast, with the proposed importance of South Asia for the initial dispersal, the archaeological or anthropological records to evaluate the different hypotheses are scarce. The oldest *Homo sapiens* remains in South Asia is in Sri Lanka (Fa-Hien Lena cave site) and dates back to ca.38,000 cal BP (Kennedy, 1999; Perera *et al.*, 2011). However, there are remains older than ca.45 ka found in easterly regions such as Laos (Demeter *et al.*, 2012), Indonesia (Barker *et al.*, 2007; Westaway *et al.*, 2017), and Australia (Bowler *et al.*, 2003). Moreover, with the absence of old human bones, researchers have mainly relied on archaeological records to infer the first arrival of *Homo sapiens* in the area (Mellars *et al.* 2013; Petraglia *et al.* 2007; 2009a; b).

There are two alternative models for interpreting South Asian Middle/Upper Paleolithic records and the timing of modern human arrival in South Asia (Fig.1). Prof. Mellars and colleagues argue that in South Asia, the Upper Paleolithic industries represented by geometric microliths are the first industry made by modern human populations (Mellars, 2006; Mellars *et al.*, 2013). His proposition is mainly based on the apparent similarity between the Indian Early Upper Paleolithic and MSA Howiesons-Poort East and South African industries. Both industries contain similar geometric microliths and a variety of symbolic artifacts such as beads or striated design motifs on ochre or ostrich eggshells. On the grounds of genetic argument, Mellars claims that the source population of the first Indian *Homo sapiens* is the one with microlithic technologies in Africa, and they dispersed from their homeland at ca. 60–50 ka (Mellars *et al.*, 2013). Though the oldest microlithic assemblage in South Asia dates back to only ca.48 - 45 ka at the Mehtakheri in Southern India (Mishra *et al.*, 2013), Dhaba in central India (Clarkson *et al.* 2020), and Fa Hien Lena sites in Sri Lanka (Wedage *et al.* 2019; Langley *et al.* 2020), Mellars and co-authors insists that because of the Holocene marine transgression, the oldest sites in the coastal area are now under the sea (Mellars *et al.*, 2013).

Conversely, multiple researchers maintain that the first South Asian industry made by *Homo sapiens* is Middle Paleolithic (Haslam *et al.*, 2010; 2012; Petraglia *et al.*, 2010; 2012; Clarkson *et al.*, 2012). Their argument principally relies on Jwalapuram (JWP) sites evidence at the Andhra Pradesh state in Southern India, where they excavated several Middle/Upper Paleolithic localities and attained several chronometric dates. At JWP, they claim that the flake-based Middle Paleolithic technology appeared before the Toba-super eruption at 74 ka, and the Middle Paleolithic population survived the eruption and persisted until ca.34–38 ka.

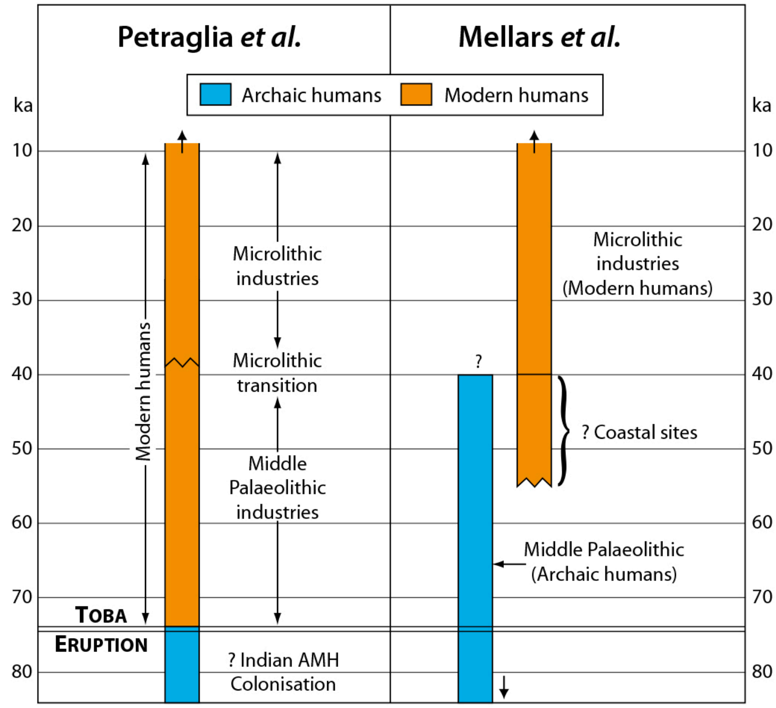

Figure 1: Two alternative models for the interpretation of South Asian Middle/Upper Paleolithic records and thus the timing of modern human arrival in South Asia (Mellars *et al.* 2013)

Furthermore, in response to the climatic condition, the Middle Paleolithic technology was transformed into the Upper Paleolithic microlithic technology at ca.35 ka (Petraglia *et al.*, 2009a). As a support for the Middle Paleolithic dispersal model, Clarkson and colleagues (2012) pointed out the similarity of core types between Indian Middle Paleolithic and South African MSA; whereas, Growcutt *et al.* (2015) and Blinkhorn *et al.* (2013; 2015; 2019) suggest the East African origin of the Indian Middle Paleolithic population based on the comparison of core technology. Some scholars supporting the model sometimes suggest the multi and older (than OIS5) dispersal from Africa (Boivin *et al.*, 2013), in clear contrast with the younger and single dispersal model of Mellars.

As several scholars point out, sound archaeological evidence for Mellars' Upper Paleolithic dispersal model and the 'coastal route' hypothesis accompanying it is rare (Korisettar, 2007; Petraglia *et al.*, 2012; Lewis *et al.*, 2014). However, given the possibility that the first peopling of Australia has been made as early as 65 ka (Clarkson *et al.*, 2017), the older "out of Africa" seems plausible. As discussed in the following sections, there remain some problems with JWP excavations and chronology. Hence, the Middle Paleolithic dispersal model cannot be fully supported; thus, the problem regarding Indian Middle/Upper Paleolithic transition and modern human arrival has not been settled yet. JWP is one of the rare South Asian sites that is systematically excavated and where many chronometric dates were attained from stratified contexts. Therefore, resolving the ambiguity in the chronology of JWP must contribute significantly to the issue. Here we present the results of new chronometric dating for several JWP Middle/Upper Paleolithic localities and discuss the implication of the new chronology.

2. Jwalapuram localities and chronology

JWP village is in Kurnool district, Andhra Pradesh of Southern India. The village lies at the bottom of the wide valley formed by Jurreru River; many archaeological sites ranging from Lower Paleolithic to the historical era are scattered at the valley bottom (Fig. 2). The research project by the British and Indian teams has located numerous localities with archaeological remains around Kurnool district,

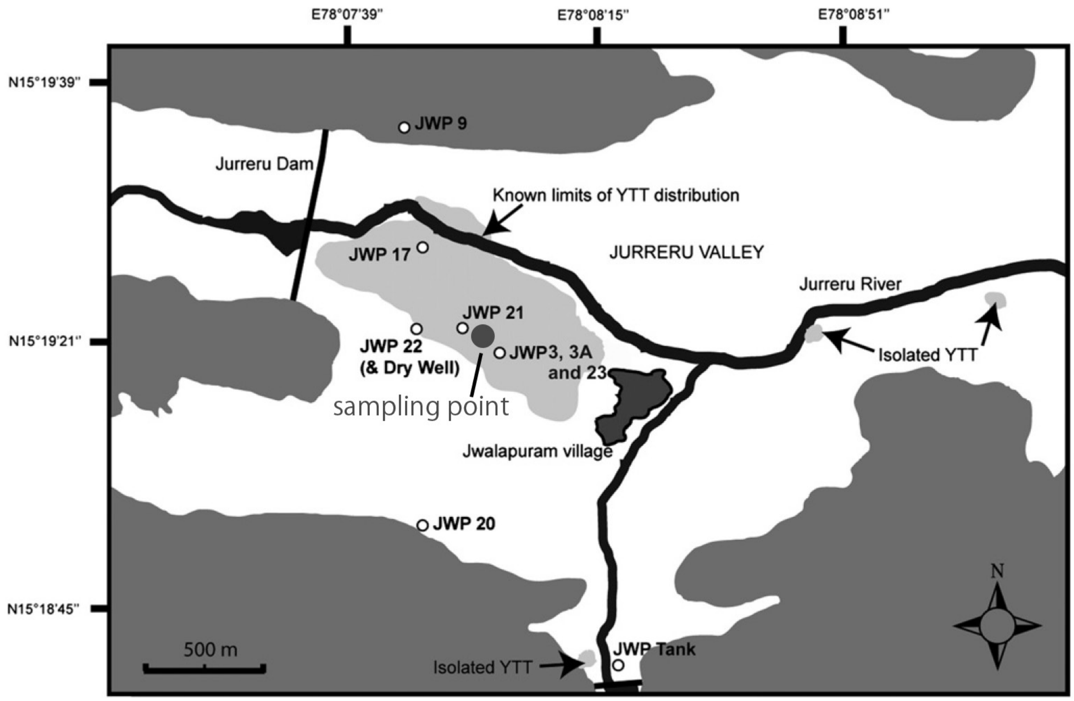

Figure 2: Jwalapuram localities (2-1) and our sampling points (2-2)
(modified after Clarkson *et al.* 2012)

including the JWP area, in the 2000s (Petraglia *et al.*, 2009b). In these archaeological sites, there are several Middle/Upper Paleolithic sites near JWP village, which are particularly important for our study. At the open-air sites distributed at the valley bottom such as JWP Locality 3, 17, 20, 21, 22, the excavations were carried out to unearth flake-based typical Indian Middle Paleolithic assemblages (Petraglia *et al.*, 2009b; Haslam *et al.*, 2010; 2012). However, at the JWP9 locality, a rock shelter is formed by a large quartzite boulder at the northern slope of the river valley, where the Upper Paleolithic assemblage consisting of backed microblades (points) and various symbolic artifacts were found (Clarkson *et al.*, 2009). Microblades were widely unearthed from upper layer A to lower layer E, and the obtained AMS dates from these layers are 11.4 -35 ka, which is within the age range of Upper Paleolithic, so it is highly possible that they belong to the Pleistocene (Petraglia *et al.* 2009b).

A sedimentological characteristic of Jurreru Valley significant for the area's chronology is the ash deposits formed by the eruption of Toba volcano in Indonesia (Jones, 2010). Mt. Toba, a large volcano in northern Sumatra, Indonesia, has erupted several times. The latest eruption, which is the biggest volcanic eruption in the Quaternary, was ca.74 ka, and its effect on the environment or human populations of the period (e.g., "volcanic winter") has been widely discussed (Chesner and Rose, 1991; Chesner *et al.*, 1991; Ambrose, 1998; Williams 2012). The ash deposits located at the JWP area are from this latest Toba eruption. It is widely distributed in South and Southeast Asia and called Youngest Toba Tuff (YTT). As in other areas where YTT deposits are documented, the YTT deposits in the JWP area can be used as a significant chronological marker for the late Quaternary (Westgate and Pearce, 2017). In JWP, several Middle Paleolithic localities contain YTT. Particularly, at JWP3, the two strata above and below YTT unearthed comparable Middle Paleolithic assemblage. This similarity in lithics (and the proximity of chronometric dates as discussed later) originally caused excavators to presume the arrival of the modern human population before ca.74 ka and its survival after the Toba eruption (Petraglia *et al.*, 2007; Haslam *et al.*, 2010).

In the JWP project, the excavators have applied chronometric dating for key strata at major Middle/ Upper Paleolithic localities. Dating was conducted on the Middle Paleolithic strata—which at some localities are found below and above YTT—using optically stimulated luminescence (OSL). However, strata belonging to Upper Paleolithic and succeeding eras were dated with AMS radiocarbon dating (^{14}C). All dates obtained for layers below YTT were older than 70–75 ka, corresponding with the tephra date, 74 ka (Haslam *et al.*, 2010; 2012). As for the stratum containing Middle Paleolithic assemblage above YTT, two groups of dates separated by a considerable time gap were initially reported. The dates ranging from ca.35–38 ka were obtained for JWP20 and JWP21, whereas stratum A above YTT at JWP3 were reported to date back to ca.74 ka, which is almost the same age as YTT itself (Petraglia *et al.*, 2009b; Haslam *et al.*, 2010). Besides, the oldest dates for Upper Paleolithic is obtained from layer D of JWP9 rock shelter: ca.34 ka (Clarkson *et al.*, 2009). These dates, especially the proximity of the latest Middle Paleolithic and the oldest Upper Paleolithic, the Middle Paleolithic below and above YTT, were initially considered as strong evidence to support the excavators' hypothesis. This hypothesis suggests the early arrival of Middle Paleolithic *Homo sapiens* populations to India, its long continuity before Toba eruption until 30–40 ka, and indigenous transition of Middle Paleolithic technology to Upper Paleolithic (Petraglia *et al.*, 2007; 2009a; 2012).

However, after the excavators' initial reports, a different view on JWP chronology was proposed. Roberts and colleagues presented a new OSL date, which implies that there are no deposits older than 55ka above YTT at□JWP (Balter, 2010; Roberts *et al.*, 2010). These new dates are in clear contrast with the original dating for stratum A above YTT at JWP3, which partly contradicts the early dispersal and indigenous MP/UP transition model, especially the continuity of Middle Paleolithic tradition after the Toba eruption. There has been no new dating of JWP deposits since Roberts' report (2010), and our study attempts to solve this ambiguity of JWP Paleolithic chronology.

3. New dating of Jwalapuram localities

We collected the samples in October 2015 and dated the Middle Paleolithic stratum of JWP localities using different samples and methods (OSL and ^{14}C). The results were close to the previous dates obtained at JWP20 and JWP21, confirming the Roberts *et al.* (2010)'s view that the date as old as ca.70 ka above YTT is likely to be incorrect. Below, the details of each method are discussed.

3.1. OSL dating

OSL dating is used to ascertain the burial age of sediments (Huntley *et al.*, 1985) by estimating the time elapsed since the sediments were last exposed to sufficient sunlight to reset the OSL clock. We collected five samples from two localities, JWP 1 and JWP 2 (Fig. 3). These locations are between JWP Locality 3 and 22. The five samples were taken from above the YTT layer. Three samples of JWP 1 were collected from the upper (JWP 1-1), middle (JWP 1-2), and lower (JWP 1-3) layers. Two samples of JWP 2 were collected from the upper (JWP 2-1) and lower (JWP 2-2) layers.

All samples were separated to 4–10 μm diameter by wet sieving in water and acetone solution. These samples were treated with 10% hydrogen peroxide and 20% hydrochloric acid. They were also immersed in 20% hydrofluorosilicic acid for 8 days to separate the quartz. The purity of the etched quartz, i.e., feldspar contamination, was verified by measuring the infrared stimulated luminescence for each sample.

All OSL measurements were made using an OSL/TL reader (NRL-99-OSTL2-KU; Neoark Corp.) (Shitaoka *et al.*, 2015) equipped with an array of 20 blue LEDs (465±15 nm). Irradiation was conducted using a small X-ray tube (dose rate 0.16 Gy/s) built into the OSL reader. The OSL of a sample was detected using PMT tube (H7360-02; Hamamatsu Photonics KK, Japan) through optical filters (Hoya U-340). Dose-response curves for palaeodose estimation were constructed using the single aliquot regenerative dose (SAR) procedure (Murray and Wintle, 2000). The SAR procedure of this study is shown in Tab. 1. Except for JWP 1-3, preheating conditions were 220°C for 60 s, and the temperature plateau was between 200 and 240°C. Additionally, JWP 1-3 was heated at 240°C for 60 s, and the temperature plateau was between 200 and 260°C.

The palaeodose values and their errors for aliquots of each sample were estimated using the Monte Carlo method (Duller, 2007; Shitaoka and Nagatomo, 2013). Radial plots (Vermeesch, 2009) of palaeodoses for each sample are presented in Fig. 4. The over-dispersion values of 0 or 9.4% for each sample were obtained. Following Olley *et al.* (2004), a sedimentary sample with over-dispersion of less than 20% was fully bleached. All samples in this study have been well bleached. The palaeodoses of all samples were calculated using the central age model (Galbraith *et al.*, 1999).

Annual doses were measured using a high-resolution gamma-ray spectrometer. The concentrations of U, Th, and K in the samples were analyzed using a Ge detector (model 7229P-7500S; Canberra). The annual doses for each sample were calculated as the sum of the alpha, beta, and gamma dose rates using the conversion factors given by Adamiec and Aitken (1998).

OSL age is calculated from the palaeodose divided by the annual dose as the absorbed dose from natural radiation per year. All OSL ages are presented in Tab. 2. The OSL ages of five samples are stratigraphically coherent within the measurement error range (Fig. 3).

3.2. C14 dating

In this study, we analyzed two shell (snail) samples from the JWP sites (Tab. 3). The sample was etched using weak HCl at room temperature to remove secondary precipitated carbonate until the weight decreased by 30%. Each sample was reacted with 100 % phosphoric acid within an evacuated glass vessel at 70°C (Wachter and Hayes 1985), and the carbon dioxide produced was purified cryogenically.

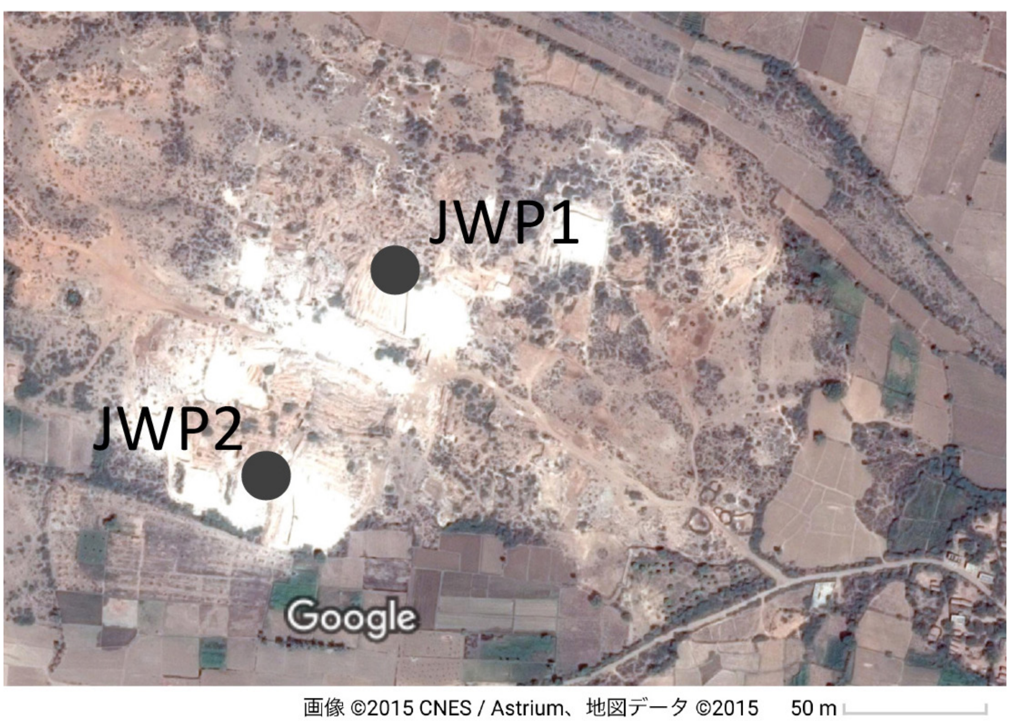

Figure 3: Photographs of sampling sections of JWP 1 (a) and JWP 2 (b)

Table 1: OSL SAR protocol for this study

Step	*Treatment*	*Observed*
1[(a)]	Give dose, D_i	-
2	Preheat (220 or 240˚C for 60 s)	-
3	Stimulate for 100 s at 125˚C	L_i
4	Give test dose, 10 Gy	-
5	Cut heat (160˚C)	-
6	Stimulate for 100 s at 125˚C	T_i
7	Stimulate for 40 s at 50˚C	-
8	Return to 1	-
(a) Step1: For the natural sample, i = 0 and D_0 = 0 Gy.		

Table 2: Results of OSL dating

Sample	*No. of aliquots accepted/ measured*	σ_{OD} *(%)*	*Paleodose Gy*	*U (ppm)*	*Th (ppm)*	^{40}K *(wt%)*	*Water content (%)*	*Cosmic dose (mGy/a)*	*Annual dose mGy/a*	*OSL age ka*
JWP 1-1	27 / 27	0	171.0 ± 2.6	2.67 ± 0.26	19.42 ± 1.27	2.15 ± 0.18	17	0.15	5.23 ± 0.16	33 ± 1.1
JWP 1-2	24 / 27	9	169.2 ± 4.3	2.89 ± 0.21	18.98 ± 1.04	2.29 ± 0.14	17	0.15	5.36 ± 0.13	32 ± 1.1.0
JWP 1-3	26 / 27	0	148.2 ± 2.4	3.24 ± 0.21	18.89 ± 1.04	2.27 ± 0.15	16	0.15	5.54 ± 0.13	27 ± 0.8
JWP 2-1	27 / 27	0	179.9 ± 2.8	2.99 ± 0.21	16.83 ± 1.04	2.32 ± 0.14	22	0.15	4.97 ± 0.13	36 ± 1.1
JWP 2-2	26 / 27	0	197.6 ± 3.2	2.93 ± 0.21	17.70 ± 1.05	1.92 ± 0.14	23	0.15	4.66 ± 0.12	42 ± 1.3

Table 3: ^{14}C ages and calibrated ages of the Jwalapuram sites.

Sample nr	*Material*	^{14}C *age*	*Calibrated age*	*Lab nr*	^{13}C *PDB*
		BP (1σ)	*cal BP (1σ)*		*(AMS, ‰)*
JWP 3	shell (snail)	32,920 ± 190	37,515-37,025	TKA-17462	-3.2 ± 0.5
JWP 4	shell (snail)	31,040 ± 150	35,565-35,215	TKA-17463	-2.4 ± 0.5

Graphite samples of 1 mg were reduced by hydrogen gas under 2mg iron powder catalyst (equivalent to 2.2 times the number of carbon moles) at 650°C for about 6h (Kitagawa *et al.* 1993). A mass spectrometer from The University of Tokyo was used to measure $^{14}C/^{12}C$ in 1 mg of carbon with international standard materials for correction (Omori *et al.* 2017). Conventional radiocarbon age was converted into calibrated age compared to IntCal20 (Reimer *et al.* 2020) by using OxCal4.4 (Bronk Ramsey 2009).

The samples used for ^{14}C dating are the gastropod shells from stratum A and B above YTT of JWP3. They have been collected at 2009 excavation by the British and Indian team, though never dated. The gastropods are known to make subsurface tunnels, and thus the ^{14}C ages obtained from their shells are possibly younger than the stratum itself. Although those shells are certainly from stratum A and B, the exact point in the stratum where they are found is not obvious. However, for cross-checking the result from OSL dating, these samples were also dated.

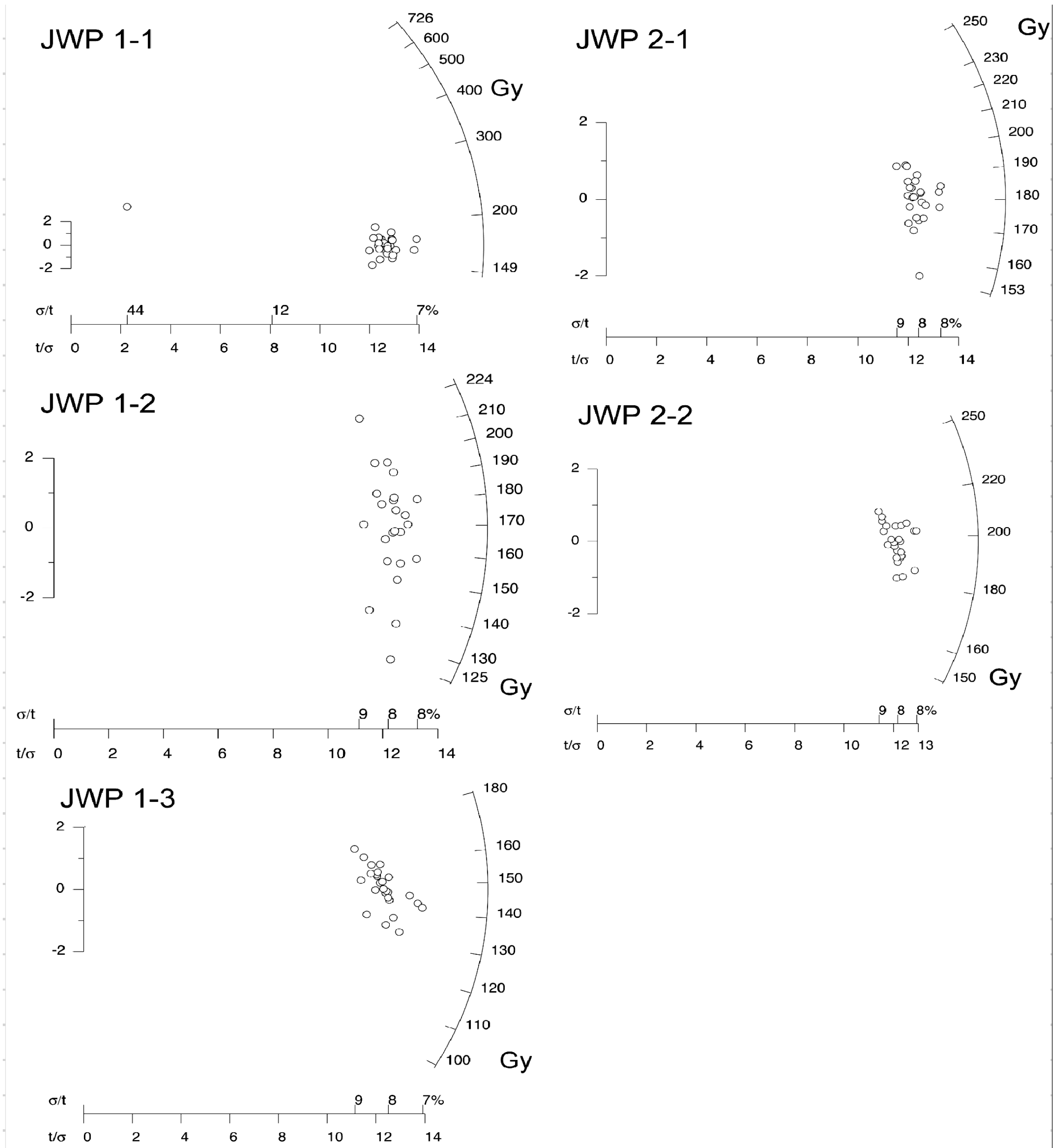

Figure 4: Dose distributions for each sample are shown using the radial plots

4. Discussion

The dates obtained from OSL and ^{14}C point to the age around 30–40 ka, corroborating the younger age of Middle Paleolithic assemblage at JWP20 and JWP21 around 35–38 ka and contradicting the originally reported JWP3 age above YTT close to 74 ka (Petraglia *et al.*, 2009b; Haslam *et al.*, 2010; 2012). In this section, we evaluate the results of our new dating and discuss the implication for Indian Middle/Upper Paleolithic age and modern human dispersal discussion.

In our study, the two different methods applied to samples from two localities indicate the same age range, thus strengthening each data's credibility. Based on the age from JWP20 and JWP21, it is likely that deposits above YTT in the JWP area are as young as 30–40 ka and the ages preceding this time range are questionable. Given the ages obtained from the stratum below YTT are correct, the time gap between strata above and below YTT amounts to almost 30000–40000 years. This implies sedimentological discontinuity after the deposition of YTT in this area. Additionally, Jones studied the sediments at several localities, including JWP3, to reconstruct the Quaternary depositional scheme of this area. The author has already mentioned the possibility of the depositional gap after the Toba ash-fall (Jones, 2010). However, her study is based on the original 74 ka date after YTT. Thus, a more detailed analysis is needed to fully understand the depositional environment after the Toba eruption.

The younger age of the Middle Paleolithic deposits above YTT is incompatible with the Middle Paleolithic population continuity originally suggested by the excavators and endorsing their indigenous MP/UP transition model. Clarkson *et al.* emphasize the overall technological homogeneity of JWP Middle Paleolithic assemblage as evidence of continuity (Clarkson *et al.*, 2012). Given its high probability, the area's Middle Paleolithic assemblages are divided with a substantial chronological gap; therefore, reevaluation of these assemblages might be needed. The situation between the Middle and Upper Paleolithic of this area is different. Here, despite the chronological proximity, the technological gap between the two is evident. The replacement of the former by the latter technology from outside rather than indigenous change cannot be readily denied. Obviously, only chronometric dates can support or reject the model, and further detailed analysis of each lithic assemblage is necessary to reconstruct the late Quaternary population history of the area.

5. Conclusions

JWP sites is a rare area in South Asia that possesses Middle and Upper Paleolithic records from a stratified context. Though the excavation of the area remarkably contributed to the discussion regarding the relationship between these two technologies in South Asia and even the modern human dispersal from Africa, the interpretation of the sites' archaeological records is puzzling. One reason for this is the problem with the chronology of the area, especially the age of the Middle Paleolithic stratum above YTT. Our research confirmed the younger age of the Middle Paleolithic stratum in JWP, 30–40 ka, using the two different methods (OSL and ^{14}C dating), thus resolving the ambiguity of the chronology. With our new dates, the proposed continuity of the Middle Paleolithic in this area is now problematic. Still, the proximity of the age of the oldest Upper Paleolithic and youngest Middle Paleolithic is corroborated. Whether these two technologies, Middle Paleolithic below and above YTT, Upper Paleolithic at JWP9 rock shelter, are locally continuous or some of them are from outside to replace previous ones, are yet to be decided. The relationship between these lithic technologies and different hominid species is also a conundrum. Still, more archaeological, geomorphological, or sedimentological studies should help rectify these problems; thus, shedding light on the debate concerning the initial history of *Homo sapiens*.

Acknowledgments

We are grateful for Drs. Dai Kunikita and Minoru Yoneda for their help in preparing this paper. This work was supported by JSPS KAKENHI Grant Numbers JP15H03261 for FY2015–2018 and JP19H01336 for FY2019–2021.

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