PRELIMINARY EXAMINATION OF BUCCAL DENTAL MICROWEAR IN JAVANESE HOMINIDS

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ABSTRACT

Ten teeth from five fossil hominid individuals from Java have been examined by environmental mode scanning electronic microscope. Eightyeight images have been analysed, in order to reconstruct ancient diet and palaeoenvironmental changes. Scratch orientation analysis indicates preferences in ancient diet and subsistence. Dental microwear analysis reflects environmental changes, some of which may be recorded in geological and palynological data.

Java is an island where anthropologists have been searching for 'the missing link' since the end of the 19th century (Dubois 1899; Koenigswald 1936, 1940; Simanjuntak 2001). In its extensive and complex geological columns and archaeological stratigraphies, a number of human fossils dated from the Lower Pleistocene to the Holocene have been discovered (Sémah 1986; Sémah *et al.* 1994). But many questions of chronology and phylogenetics in human evolution in Java are still unresolved at present, and furthermore, the study of dental microwear in these fossil hominids is still inadequate (Pastor 1992).

Dental microwear study, which has been practiced by anthropologists for more than twenty years, is an integrated discipline that incorporates dietary, masticatory functional and palaeoenvironment approaches. Analysis of micro-striations on the surfaces of tooth enamel has been carried out on both extinct and extant primate species, including fossil hominids and recent human remains from archaeological sites (Rose and Ungar 1998; Teaford 1991). Diet, feeding adaptation, ingestion behavior and style of subsistence are important factors in research into the origins of 'culture' in the anthropological sense (Kroeber 1952; Kroeber and Kluckhohn 1952). For some primatologists, diet is even acknowledged to be the most important parameter underlying the behavioural and ecological differences among living primate species (Fleagle 1988; King *et al.* 1999a; Teaford and Walker 1984; Teaford 1991; Mainland 1995).

The dental microwear caused by masticating food is produced by abrasion. Sources of abrasion can be phytoliths contained in vegetable cells (Danielson and Reinhard 1998; Pearsall 2000; Gügel *et al.* 2001), sand grains and dust adhering to food surfaces (Kay and Covert 1983; Ungar *et al.* 1995), grains of sand liberated in preparing food (Lalueza *et al.* 1996; Teaford and Lytle 1996; Ungar and Spencer 1999; Schmidt 2001), and bone gnawing (Peters 1982), although the latter usually makes much larger striations than the others. Comparative studies indicate that a vegetarian diet produces more microwear (striations) than an omnivorous one, and more than a carnivorous diet in the same environmental conditions (Lalueza *et al.* 1996).

HISTORICAL REVIEW

Dental microwear studies began in the late 1950s, when Baker *et al.* (1959) observed dental microwear in domestic sheep using a luminous microscope. Dahlberg and Kinzey's research (1962) was the first study of dental microwear carried out on human teeth. The technique of scanning electron microscopy (SEM) was first applied in anthropology in the 1970s. Walker *et al.* (1978) compared dental microwear in two species of wild hyrax: *Procavia johnstoni* (a grazer) and *Heterohyrax brucei* (a browser). This was the first comparative research in dental microwear. Study of the diet of fossil hominids by analysis of dental microwear also began in the 1970s (Puech 1976, 1979), and continued to develop progressively with expansion into non-human primates throughout the 1980s (Puech *et al.* 1983, 1986; Grine 1986; Grine and Kay 1987; Grine and Franzen 1994).

For more than two decades, most research focused on occlusal surfaces (Ungar and Teaford 1996; Rose and Ungar 1998). But further studies in the 1980s of masticatory mechanisms suggested that occlusal microwear is also produced by simple attrition between upper and lower teeth (enamel prism-plucking), and not just by abrasion of food particles (Gordon 1982; Puech 1984; Ungar and Teaford 1996). Consequently, studies of diet have now transferred to consideration of non-occlusal (buccal and lingual) tooth surfaces (Pérez-Pérez *et al.* 1994, 1999; Lalueza *et al.* 1996). Qualitative examinations of dental microwear on buccal surfaces began in the 1970s (Fine and Craig 1981; Puech 1976, 1979, 1983). Quantitative studies commenced in the 1990s (Lalueza *et al.* 1996) and today represent the mainstream in dental microwear study (Rose and Ungar 1998). Furthermore, many studies have shown that the dental microwear from food abrasion on molars is greater than on the other teeth (Ryan and Johanson 1989; Kelley 1990; Kelley and Larsen 1991; Ungar 1994; Bax and Ungar 1999).

The quantitative approach in dental microwear study developed greatly in the 1980s (Gordon 1982; Krause 1982; Gordon and Walker 1983; Walker and Teaford 1989; Maas 1991; Rose and Ungar 1998). Comparative studies have been carried out on living primates in nature and in the laboratory (Teaford and Oyen 1989a; Teaford and Glander 1991; Burnell *et al.* 1994), and from palaeo-biological and bioarchaeological per-spectives (Ungar and Teaford 2002).

THE SAMPLES

The samples examined consist of 10 molar teeth (lower and upper) from 5 individuals recovered from archaeological contexts in Java. Four individuals are from Sangiran, these being Sangiran 27, Ardjuna 9, and two isolated molars (NG91 G10-1 and NG92 D6 ZE 57s/d 76), all identified as *Homo erectus.* The fifth individual was a burial in Song Terus cave, attributed to *Homo sapiens* (Widianto 1991, 1993; Grimaud-Hervé and Widianto 2001; Detroit 2002; Lee 2002; and see Simanjuntak and Asikin 2004, this volume).

Sangiran

Seven teeth from four *H. erectus* individuals were examined from Sangiran: the upper left M1, M2, and upper right M2 of Sangiran 27; the lower right M2 and M3 of Ardjuna 9; and two isolated teeth (NG91 G10-1 upper left M2, and NG92 D6 ZE 57s/d 76 lower right M2) (Widianto 1991, 1993).

Sangiran 27 originates from the Pucangan layers at Sangiran, dated to the Lower Pleistocene and composed of black clay interrupted by diatomite and tuff layers (Figure 1). The early Pucangan environment was marshy with lagoons and the coastline was nearby, as indicated by the presence of mangrove pollen. Rain forest dominated the background at this time. The late Pucangan environment shows more continental characteristics, with open forest vegetation suggesting a marked dry season.

The level that contains Ardjuna 9 is the Grenzbank, between the Pucangan and the overlying Kabuh layers. This calcified conglomerate dates from the end of the Lower Pleistocene and is associated with marine and continental materials, the latter marking the end of marine deposition in this region. The environment at this time was open and herbaceous.

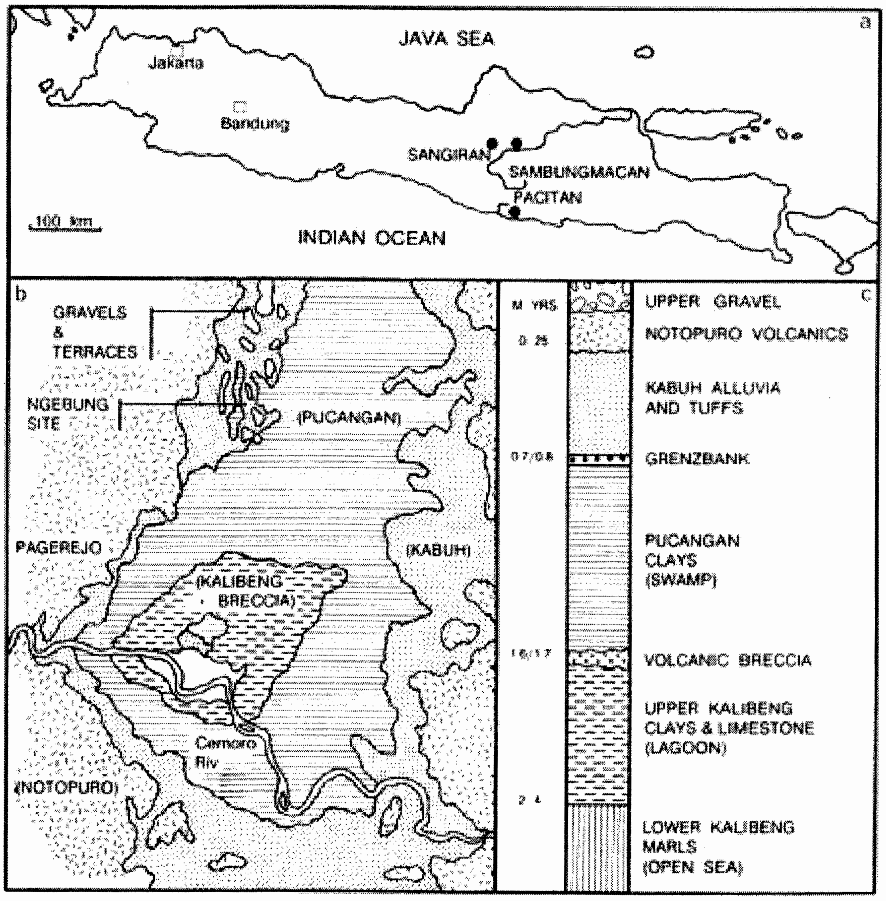

Figure 1: Location and stratigraphy of Sangiran dome (map drawn by Anne-Marie and François Sémah).

The Kabuh layer yielded the two isolated teeth. This consists of volcanic and alluvial sediments and dates to the Middle Pleistocene. The pollen spectrum shows an open vegetation with Poaceae, Asteraceae, Fabaceae and Mimosaceae, and a climate much drier than that of Pucangan times (Sémah 1984, 1993, 1998; Sémah and Sémah 2001; Sémah, F. 2001). All three layers are associated with faunas that were presumably hunted by the hominids (Sondaar 1984; Vos *et al.* 1993; Vos and Long 2001; Moigne *et al.* 2004).

Song Terus

The karstic cave of Song Terus (Figure 2), that provided the sample Song Terus 5876 A/B (a burial), is located in the Punung region in East Java at an altitude of 333 m. It is about 100 m long and 20 m wide (Gallet 2004; Sémah *et al.* 2004). Palynological data indicate regional environmental oscillation. Dry climate vegetation dominated the area at the end of the Pleistocene, and was replaced during the Holocene by tropical rain forest. The burial that was studied belongs to the beginning of the Holocene (Sémah *et al.* 1994, 2004), and was associated with the Keplek Period assemblage and fauna described by Simanjuntak (2001), Detroit (2002), Simanjuntak and Asikin (2004, this volume), Gallet (2004) and Sémah *et al.* (2004). The three teeth analyzed in this study are upper left M1, M2, and upper right M2.

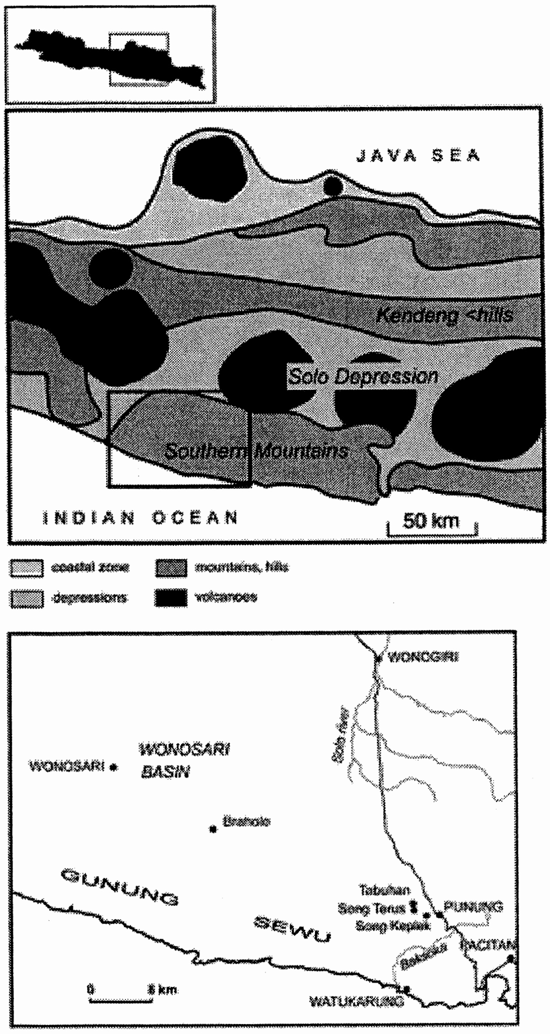

Figure 2: Location of Song Terus cave (Sémah et al. *2004).*

THE ANALYSIS

Examinations of buccal surfaces were conducted using high-resolution negative silicon replicas taken from the original fossil teeth in Java. The casts were prepared following conventional epoxy resin procedures (Rose 1983; Teaford and Oyen 1989b) at Musée de l'Homme in Paris. All the samples were scanned, observed and recorded by the environmental mode electronic microscope, a Phillips XL30 ESEM (Deniaux 2002), located in the Centre Européen de Recherches Préhistoriques de Tautavel, France. The scanning zone is shown in Figure 3. The images were taken at a magnification of 500x with a scale bar of 50 mm.

From 10 to 20 images were taken for each sample when microwear was present, but only those without taphonomic modification or too much concretion were actually analysed, in order to ensure a focus purely on ante-mortem microwear. The recorded images were analysed by Microware 3.0 and 4.0, two software programs developed by P.S. Ungar (1997). Descriptive statistics (length, width, orientation, plus means and standard deviations) were recorded in Excel. The differences in patterns between areas with and without microwear were very distinct, and the scanned surfaces were usually covered with a large number of striations whenever microwear was present.

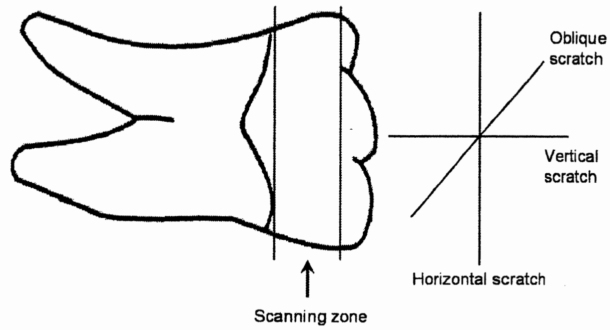

Figure 3: Scanning zone of SEM and categories of scratch orientation. Orientation value between 67.5° and 112.5° with respect to the occlusal-buccal border are 'horizontal'. Values between 22.5° and 67.5°, and between 112.5° and 157.5°, are 'oblique'. Those between 0° and 22.5°, and between 157.5° and 180°, are 'vertical'.

Striations are conventionally divided into two categories: *scratch* (of which the length is four times or more greater than the width) and *pit*. Both categories are identified and recorded automatically in the Microware software. For recording the orientations of scratches, a system modified from Puech (1982) and Pérez-Pérez *et al.* (1994) was used. In characterizing the orientation of scratch, values between 67.5° and 112.5° with respect to the occlusal-buccal border are 'horizontal'. Values between 22.5° and 67.5°, and 112.5° and 157.5°, are 'oblique'. Those between 0° and 22.5°, and 157.5° and 180°, are 'vertical' with respect to the occlusal-buccal border (Figure 3).

RESULTS

Eighty eight images from 10 sample teeth were analyzed. From the bar chart of the numbers of scratches and pits identified on each tooth (Figure 4), we can see most of the striations are identified as 'scratches', while 'pits' are much fewer. The mean values of scratches and pits for the four individuals from Sangiran (Table 1) show differences among the individuals from the three main stratigraphic levels within the Sangiran Dome: Sangiran 27, from the Pucangan level, dated lower Pleistocene, preserved the least quantity of scratches; two Ngebung teeth from the Kabuh level, dated middle Pleistocene, preserved a much higher quantity of scratches; and Ardjuna 9, from the Grenzbank level, dated late lower Pleistocene, preserved an intermediate scratch quantity.

Figure 5 shows the distribution of and variations in scratch orientation, as calculated from the micrographic images in degrees. Most of the images of Sangiran 27 and Song Terus 5876 A/B show vertical orientation (0° to 22.5° and 157.5° to 180°). Those of NG91 G10-1 and NG92 D6 ZE 57s/d 76 are mainly distributed in the category 'oblique' (67.5° to 22.5° and 112.5° to 157.5°). Most of the images of Ardjuna 9 show oblique and cross orientations dominant, but some images are horizontal-dominant.

The SEM images also show the dominance of scratch orientation. For example, vertical scratches are dominant in the image of Sangiran 27 (Figure 6), and that of Ardjuna 9 shows horizontal and oblique scratches dominant (Figure 7).

Table 1: Mean values of scratches and pits for each sample

	Sangiran 27	Ardjuna 9	Ng 91	Ng 92	Song Terus 5876
Mean value of scratch number	61.4	70.2	78.9	86.3	86.4
Mean value of pit number	4.6	5.6	4.5	7.7	8.3

DISCUSSION AND CONCLUSIONS

Although the sample analysed was small, the results still provide abundant and useful data. Taphonomic factors can erode fossil teeth surfaces and erase ante-mortem microwear, but they cannot increase them (King *et al.* 1999b; Ungar and Teaford 1996; Grine 1986). Taphonomic factors can also give rise to pits on non-occlusal surfaces (King *et al.* 1999b; Pérez-Pérez *et al.* 2003), although pits appear rarely on buccal surfaces in the analysed samples, implying that the sedimentary conditions have been favourable for dental microwear study.

Comparative microwear studies on non-human primates and small mammals show that microwear striation patterns change under differing vegetable diets, as determined by different ecosystems and even seasonal vegetation changes (Teaford and Robinson 1989, Teaford and Runestad 1992). Our results also reveal differences between samples from different palaeoenvironments. The scratch density of Sangiran 27 is lower than that of Ardjuna 9, and that of Ardjuna 9 is lower than that of the two isolated teeth from Ngebung (Table 1). According to palynological data, the Pucangan (Sangiran 27) was environmentally more humid than the Kabuh (Ngebung), while the Grenzbank in-between (Ardjuna 9) appears to have been intermediate. The dental microwear results are in accord with this.

The relationship between scratch orientation and dietary preference has been studied qualitatively by Puech (1976, 1979; Puech *et al.* 1983), and quantitatively by Lalueza *et al.* (1996). Lalueza et *al.* (1996) have examined scratch orientation with respect to masticatory mechanism in extant human populations. The results suggest that a carnivorous diet correlates with a dominance of vertical scratches, whereas a vegetarian diet leads to more horizontal scratches, and an omnivorous one leads to a mixture between horizontal and oblique.

We propose, therefore, that the Sangiran 27 (marshy environment, humid climate) had a largely carnivorous diet. Ardjuna 9 (open and herbaceous environment) had an intermediate diet between omnivorous and vegetarian. NG91 G10-1 and NG92 D6 ZE 57s/d 76 (open and herbaceous environment, dry climate) had largely an omnivorous diet. Song Terus 5876A/B, like Sangiran 27 living in a humid forested environment, also had a carnivorous diet. The mandibular cheek teeth of Song Terus 5876 A/B also carried a particular macro-wear pattern (Fig 8) that Puech and Puech (1993) suggest might be due to a consumption of dried fish, or use of the teeth as a third hand for producing fishing nets (Ubelaker *et al.* 1969; Chang 1993).

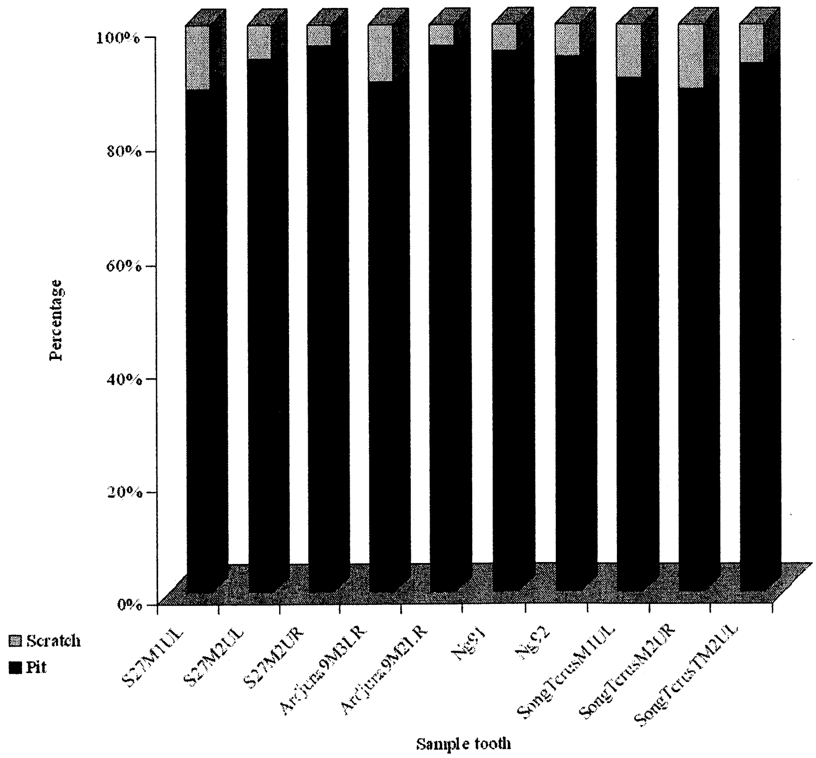

Figure 4: Numbers of scratches and pits for each sample.

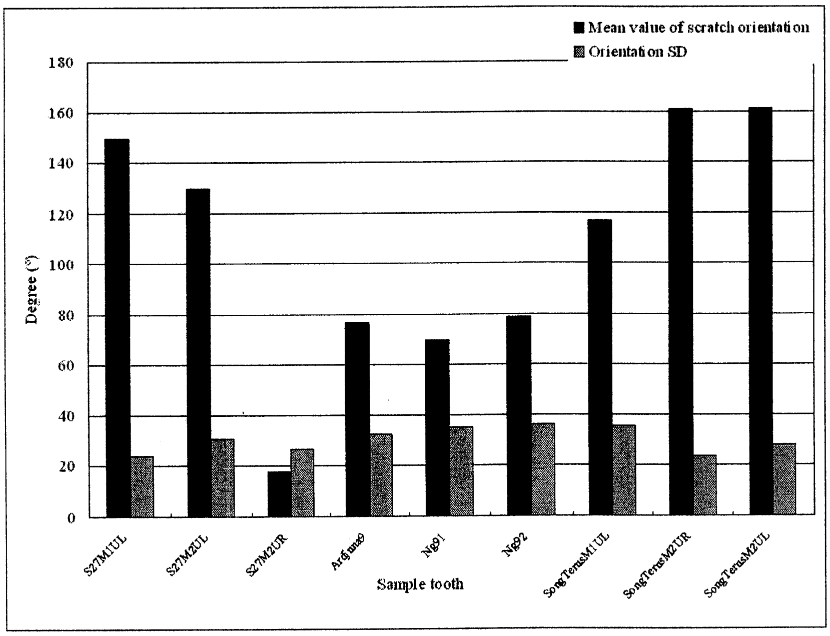

Figure 5: Distribution of scratch orientation angle by tooth. The black bar signifies mean value by degree, the grey bar signifies the standard deviation.

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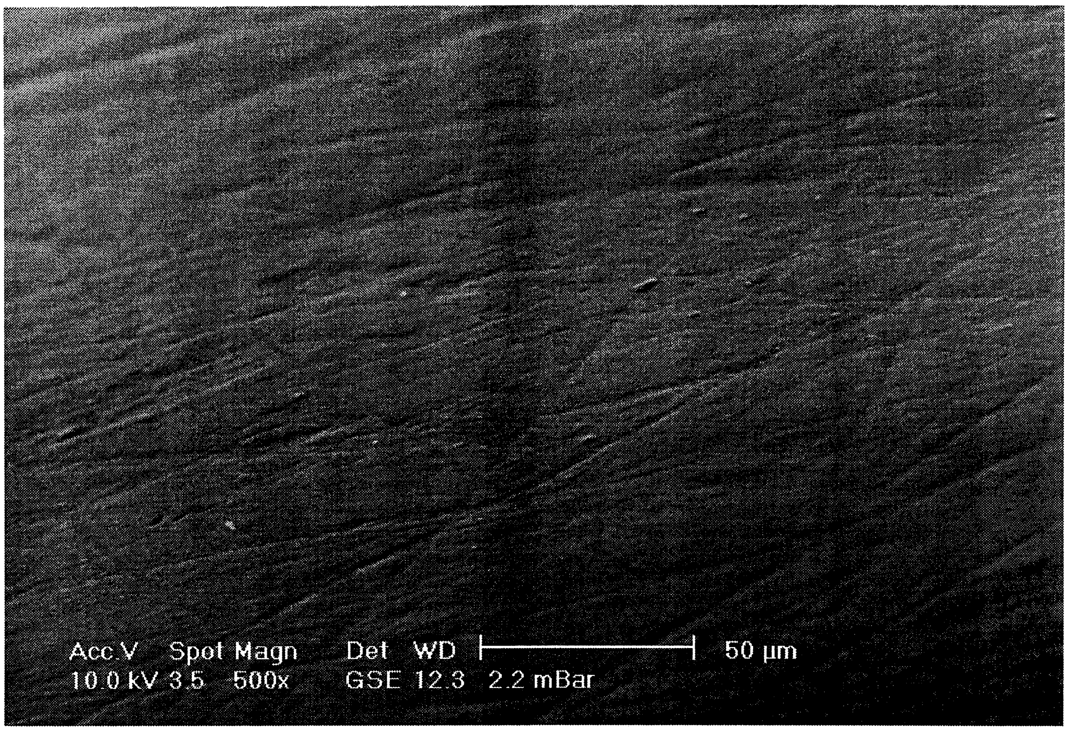

Figure 6: SEM image of Sangiran 27 showing vertical (to occlusal border in right side) scratch dominant.

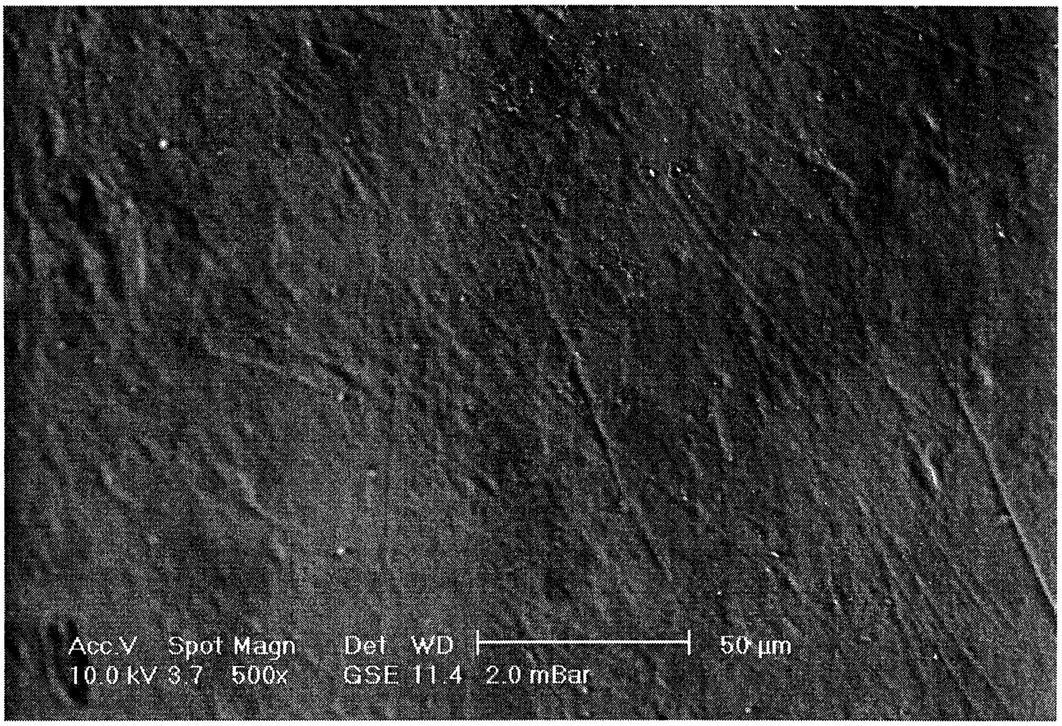

Figure 7: SEM image of Ardjuna 9 showing oblique scratch dominant.

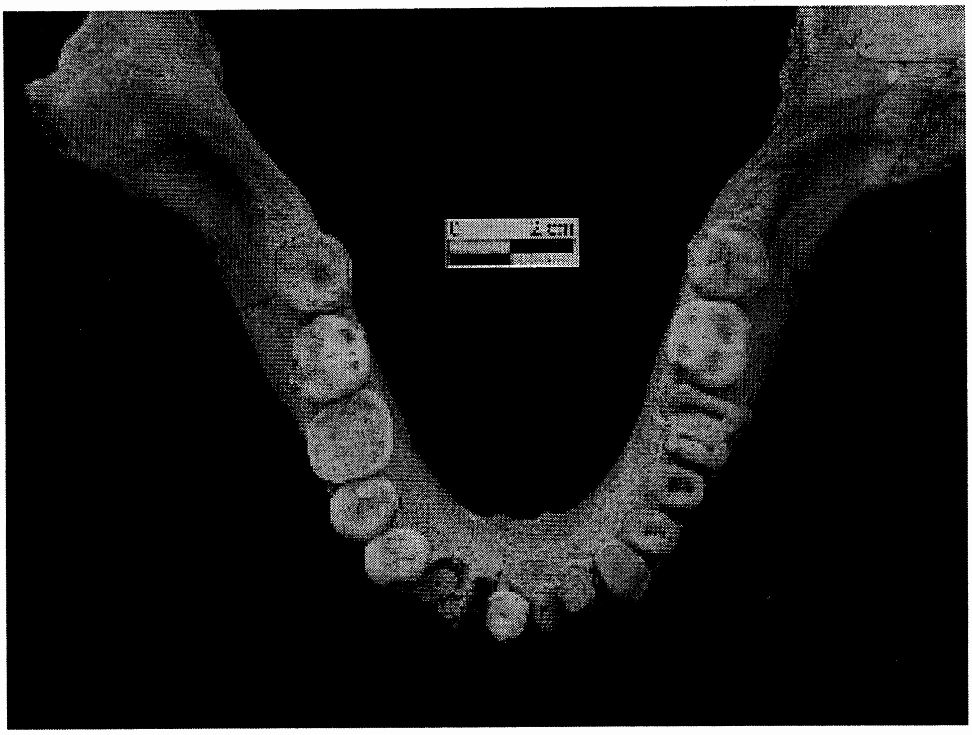

Figure 8: Macro wear pattern on lower molars of Song Terus burial mandible.

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