OCCURRENCE OF SILICOFLAGELLATE *Mesocena elliptica*: FURTHER EVIDENCE ON THE AGE OF THE WAKIMOTO FORMATION, OGA PENINSULA, JAPAN AND THE RECOGNITION OF THE JARAMILLO EVENT

TSUNEMASA SAITO* and LLOYD H. BURCKLE*

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Introduction

The Late Cenozoic strata exposed on the Oga Peninsula, on the Sea of Japan side of northeast Japan, have been the subject of intensive study since as far back as 1918 and the sedimentary sequence established there has come to be widely regarded as a standard for the correlation of Japanese Neogene formations. This strong interest stems partly from this area being one of the important oil-producing regions of Japan and also partly because of the rich fossil flora and fauna contained in the Oga sediments. The following eight formations have been established from oldest to youngest: Nishioga, Daijima, Nishikurosawa, Onnagawa, Funakawa, Kitaura, Wakimoto, and Shibikawa (HUZIOKA, 1959; IKEBE, 1962; MINATO *et al.*, 1965).

For many years, the Miocene-Pliocene boundary was considered to be at the base of the Wakimoto Formation and the Pliocene-Pleistocene boundary well above the top of the Shibikawa Formation (*e. g.* MINATO *et al.*, 1965). Recent studies of planktonic microfossils and paleomagnetic measurements, however, suggest considerable revision of the ages of these strata, generally making their ages much younger than hitherto considered.

On the basis of diatom floras, BURCKLE (1971) suggested that the upper part of the Funakawa Formation and the Kitaura Formation, which were placed previously in the

Miocene, should be assigned to the upper part of the Pliocene. KIMURA (1972) first reported the magnetic polarity reversal sequence covering an interval from the Funakawa to the Wakimoto Formations and correlated the normal polarity zone observed in the upper Wakimoto with the Gauss Normal Epoch and the reversed polarity zone in the lower Wakimoto-Kitaura Formations with the upper part of the Gilbert Reversed Series. KENT (1973) measured the magnetic reversal sequence of the same stratigraphic interval and his results were very similar to those reported by KIMURA (1972). Incorporating personal discussions with BURCKLE, MAIYA & SAITO on microfossil data from the Oga section, however, KENT (1973) differed from KIMURA in suggesting a correlation of the Wakimoto normal polarity zone with a part of the Olduvai Event or even with the Jaramillo Event. In 1973, TAKAYAMA reported the discovery of one calcareous nannofossil *Gephyrocapsa oceanica* KAMPTNER from the lowermost part of the Wakimoto and essentially confirmed the correlation given by KENT. Three subsequent publications by KIMURA (1974), KITAZATO (1975), and TAKAYASU & MATOBA (1976) resolved many of the problems in correlation. These authors assigned the lower, normal polarity zone occurring in the upper part of the Funakawa Formation [according to KIMURA (1974); but in the lower part of the Kitaura Formation, according to the redefined terminology of KITAZATO (1975) and TAKAYASU & MATOBA (1976)] to the Olduvai Event and the reversed polarity zone in the lower Wakimoto-Kitaura to the

* Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964.

Kimura, 1974

This paper

Fig. 1. Paleomagnetic stratigraphy and stratigraphic succession of the southern coast of Oga Peninsula after KIMURA (1974).

Magnetic polarity interpretation and position of samples bearing *Mesocena elliptica* (EHRENBERG), discussed in this paper, are shown to the right. Location of sites at which samples for microfossil analyses were collected shown in Fig. 2. Letter symbols preceding sample number omitted.

upper Matuyama Reversed Series (Fig. 1). One question which has not as yet been satisfactorily resolved is the correlation of the upper, normal polarity zone observed in the Wakimoto Formation. KIMURA (1974) regarded the normal interval to be that of the Brunhes Epoch with the Jaramillo interval being missing here. MAIYA *et al.* (1976, p. 404), on the other hand, interpreted the normal interval as the Jaramillo Event, thereby advocating the continuity of sedimentation.

We now report the discovery of the silicoflagellate *Mesocena elliptica* (EHRENBERG) from the Wakimoto Formation, a species which is known to have become extinct shortly after the Jaramillo Event, and shed additional light on the problem of correlating the normal polarity zone of the Wakimoto Formation with the standard magnetic reversal sequence.

Discussion

MUKHINA (1963, 1966) was the first to point out that *Mesocena elliptica* (EHRENBERG) occurs in the Pleistocene of the equatorial Pacific and that it has a very limited range. This short range was substantiated by HAYS *et al.* (1969) and was found to bracket the Jaramillo Event. BURCKLE (1972) amplified on these findings and further reported that this form occupies the same stratigraphic range in the equatorial Indian Ocean. LING (1970) discussed the apparently anomalous occurrence of this "Tertiary" form in the Pleistocene and reported that it also occurred in the Pleistocene of the North Pacific—probably correlative in time with the equatorial occurrence. He pointed out that the finding of this species in the Miocene and Pleistocene, with no record of it in the Pliocene, is a problem that still remains to be solved.

A partial solution to this problem was provided by BUKRY & FOSTER (1973) who reported on the continuous occurrence of this form from the Late Pliocene to Middle Pleistocene in the easternmost equatorial Pacific. They, thus, provided us with the basis for believing that this species survived from the Miocene to Pleistocene by living largely in upwelling areas. BURCKLE & OPDYKE (in press) re-examined the material of BUKRY & FOSTER

(1973) and confirmed that *M. elliptica* does indeed range down into the Late Pliocene. They further found that the last appearance of this species in the easternmost equatorial Pacific was correlative with its last occurrence in the central equatorial Pacific.

The synchronicity of the last occurrence of *M. elliptica* is an important point. In two separate reports on the North Pacific, BURCKLE & OPDYKE (in press) and BURCKLE & HAMMOND (in prep.) demonstrate that the last occurrence of this species is between the top of the Jaramillo and the base of the Brunhes—coincidental with its last occurrence in the equatorial regions of the Pacific and Indian Oceans. In order to better understand the nature of this last occurrence, BURCKLE (in press) discovered that it was coincidental with the beginning of Isotopic Stage 22 of SHACKLETON & OPDYKE (1976). These authors identify this isotopic stage as representing the "first major Northern Hemisphere continental glaciation of middle Pleistocene character". It seems therefore, that there is a climatic connection to the last occurrence of *M. elliptica*.

We can now focus our attention on the Wakimoto Formation of the Oga Peninsula and upon the interpretation of the normally magnetized sediments in the upper part of the formation (KENT, 1973). This normal section has been correlated with the Brunhes Epoch by KIMURA (1974), but KENT (1973) and MAIYA *et al.* (1976) labelled it as the Jaramillo. The samples used for this study were collected from a stratigraphic section along the southern coast of the Oga Peninsula, situated west of Wakimoto, Oga City, Akita Prefecture (Fig. 2). Rock samples from each site consisted of two geomagnetically oriented blocks and the paleomagnetic stratigraphy established for the section was reported by KENT (1973, figs. 2c, 7). The paleomagnetic stratigraphy of KIMURA (1974) for the Wakimoto and Kitaura Formations was also based on this section.

The first occurrence of *M. elliptica* in the Wakimoto is in our sample O-W-29, just below the normally magnetized section (Fig. 1). The next set of samples above this are

Fig. 2. Location map of samples used for this study.

The locality lies on the southern coast of the Oga Peninsula, situated west of the town of Wakimoto, Oga City, Akita Prefecture. Those numbers preceded by O-W indicate samples representing the Wakimoto Formation and those preceded by O-K the Kitaura Formation.

Fig. 3. *Mesocena elliptica* (EHRENBERG) from the Wakimoto Formation.

The two photographs on the left were taken from sample site O-W-32 and the one on the right was taken from sample site O-W-41. The black bar beneath central photo is 20 microns in length.

generally barren of biogenic opal or have diatoms and silicoflagellates in low abundance. In such samples, only dissolution resistant forms are unbroken while the majority of the forms are in fragments.

Sample O-W-40 and O-W-41, which are in the normally magnetized section, contain a few broken specimens of *M. elliptica*. On this basis, we conclude that at least a portion of the normally magnetized section is Jaramillo

in age. We cannot rule out the possibility, however, that Brunhes age sediments are sitting directly on top of the Jaramillo.

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珪質鞭毛虫 *Mesocena elliptica* の発見と男鹿半島脇本層における
Jaramillo 亜期の確認

斎藤常正・L. バークル

(要 旨)

男鹿半島南岸に露出する船川層から脇本層にかけての堆積岩の磁気層序は、KENT (1973) および KIMURA (1974) によって記載され、正磁極方向を示す二つの顕著な層準が認められた。そのなかで、船川層上部に認められた正磁極方向の層準は、Matuyama 逆磁極期中の Olduvai 亜期に対比されることとして異論がないが、脇本層上部に認められた、上位の正磁極層準については Matuyama 期の Jaramillo 亜期に対比する考え方と、最も若い Brunhes 正磁極期に相当するとする考え方がある。意見が分かれていた。

太平洋各地から得られた深海底コアの研究によると、浮遊性珪質鞭毛虫 *Mesocena elliptica* (EHRENBERG) 種の絶滅が Jaramillo 亜期のすぐ後に起っている。脇本層中の珪質鞭毛虫を今回検討したところ、*Mesocena elliptica* の産出が認められ、その結果脇本層上部の正磁極方向に帯磁した層準の一部は、Jaramillo 亜期に対比されることが確認された。珪質鞭毛虫の産出は、脇本層最上部では連続していないので Jaramillo 亜期の堆積物が直接不整合で Brunhes 期の堆積物におおわれている可能性は否定できない。