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Paleaogeography and Climatic Change recorded on Viviparidae Carbon and Oxygen Isotope in Mae Moh Coal Mine, Northern Thailand

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Abstract: Viviparidae fossil collected from the R-, Q-, and K-coal zones of the Mae Moh coal mine, northern Thailand were analyzed for ^{13}Carbon and ^{18}Oxygen isotopes at Akita University, Japan. The result reveals that Viviparidae of the lower part of the coal mine contribute much heavier carbon isotopes than the upper part. The results revealed that Viviparidae shell ^{13}C values are between 3.52 to 6.92 ‰ PDB in the R-coal zone, between 4.17 to 5.77 ‰ PDB in the Q-coal zone and between 1.41 to 1.34 ‰ PDB in the K-coal zone. For oxygen isotopes the lower part of the basin showed heavier isotopes than the upper part, where the ^{18}O values are between -3.15 to -5.10 ‰ PDB in the R-coal zone, between -4.19 to -6.04 ‰ PDB in the Q-coal zone, and between -7.05 to -8.04 ‰ PDB in the K-coal zone. The isotope valued of Viviparidae shells collected in the Kew Lom reservoir in the Lampang area yielded ^{13}C values between -11.01 to -12.19 ‰ PDB and the ^{18}O ‰ value between -6.64 to -7.04 ‰ PDB. The isotopic results of Viviparidae fossil shells from Mae Moh basin show the gradually change from the R-coal zone to the Q-, and the K-coal zone and significantly different from the Recent Viviparidae in the area. The heavy carbon isotopes in the R-coal zone could imply a much cooler climate than during the Q- and K-coal zone depositing period and the area were more close to the sea. The climatic condition during the Q- and K-coal zone depositing period was warmer and at a geographically higher elevation or latitude than during depositing the R-coal zone. The changing records in Mae Moh coal field are confirmed by temperate fossils in the other Oligocene to Lower Miocene basins in Northern Thailand. The change to a more tropical climate could have occurred during the Middle Miocene period, as indicated by paleomagnetic age dating in the K- and Q-coal zone. The northward movement of the Australian-Indian plate and collision with the Eurasian plate are suspected to be the main cause of the change.

Keywords: carbon isotope, oxygen isotope, Viviparidae, climatic change, paleaogeography, Mae Moh coal mine, Miocene, Australian-Indian plate, Eurasian plate, Thailand

1. Introduction

The Mae Moh coal mine is operated in the largest coal deposit in Thailand. It is situated in Mae Moh basin, Lampang province, northern Thailand. Each day, and approximately 40,000 tons of coal of lignite to sub-bituminous C in rank (ASTM, 1988) are mined for 10 units coal-fired power plants (total of 2400 MW) in the mining area. The mine pit covers an area of 4 x 8 km^2 at depths varied up to 200 meters. During the exploration drilling and excavation, there were many shell beds, mainly gastropods, which have been found associated with the coal beds, and some of these are used as key beds. The important shell beds used as keys beds are those below the R-coal zone, below the Q-coal zone, and the most important bed, due to the great thickness of Vivipridae shell (maximum 12 meters), lying between the K3- and K4-coal zone. During the mining history, this shell bed has shown to be only 4 meters thick in the northeastern pit. Later, when the southwest pit was opened, the largest part of the shell bed in terms of thickness and width, consists of nearly 100 percent pure *Bellemya* sp. without clays intercalation are shown (Plate 1). The environment of depositions of these shell beds become interested and required investigation. Isotopic analysis is one of the tools in this investigation. The important of this method is the possibility to interpret the role of changing depositional environment.

2. Geology of the Mae Moh Basin

Mae Moh coalfield is the largest Tertiary coal deposit

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in Southeast Asia. It is located at latitude 18°18’21”N, longitude 99°44’02”E, in Mae Moh District, Lampang Province, approximately 631 kilometers north of Bangkok and 26 kilometers east of Lampang township. The basin is bounded mostly by marine Triassic rocks of Lampang Group (Fig. 1), which are composed of limestone, shale, and sandstone. Exceptionally, in the southern part of the basin, the Tertiary sequence is overlain by the Quaternary basalt (Sasada *et al.*, 1987; Charoenprawat *et al.*, 1995; Chaodamrong and Burrett, 1997). Unconsolidated sediment of fluviatile deposits form a thin veneer throughout the basin. It consists of superficial gravel deposits in the lower part, lacustrine to fluviolacustrine in the middle part and alluvium deposits in the upper part (Chaodamrong, 1985; Jitapankul *et al.*, 1985; Uttamo *et al.*, 2003).

The Tertiary sequences of Mae Moh basin (Mae Moh Group) have been divided into three formations (Fig. 2). Each formation consists of sediments that strongly differ in lithology, sedimentary structures, degree of con-

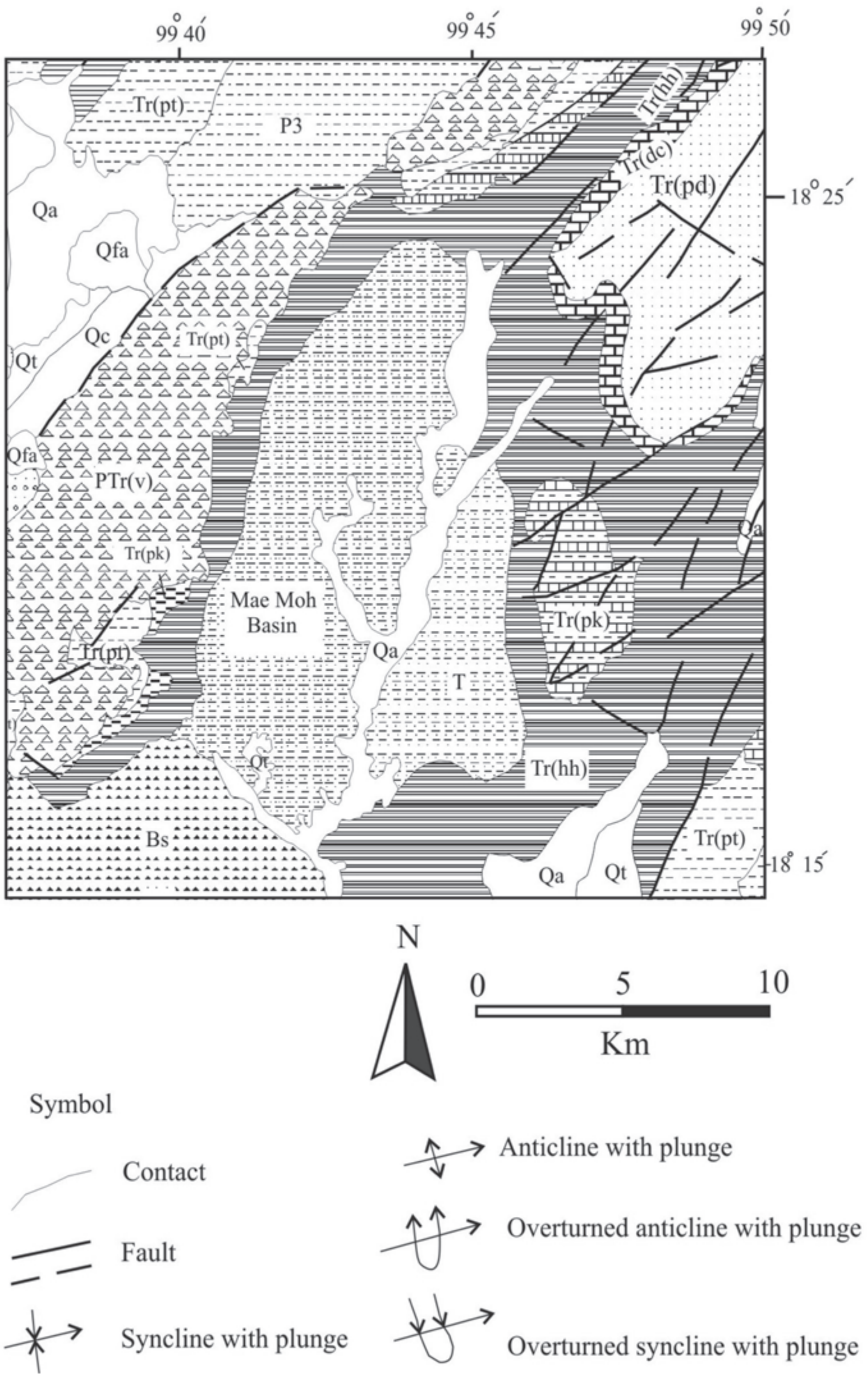

Fig. 1 Geologic map of Mae Moh basin (modified from Charoenprawat *et al.*, 1995).

Legend	Age	Rock Unit	Description
Sedimentary rock			
Qfa	Quaternary	Mae Taeng Group	Alluvial fan sand and clay unit: sand, clayey and silty, light gray, interbedded with sandy clay.
Qa	Quaternary	Mae Taeng Group	Alluvial deposits: gravel, sand, silt, clay and mud.
Qt	Quaternary	Mae Taeng Group	Terrace deposits: gravel, sand, silt, clay, and lateritic soil.
Qc	Quaternary	Mae Taeng Group	Colluvial unit: rock fragments, gray, orangish red, covered with clayey sand and laterite.
T	Tertiary	Mae Moh Group	Interbedded claystone, sandstone, mudstone, diatomite, coal, and shale with fossil leaves, stems, bone of fish, and *Viviparus* sp. and vertebrate remains.
	Lampang Group		
Tr(pd)	Triassic	Pha Daeng Formation	Sandstone, red to reddish brown, cross-bedded; siltstone, conglomerate and shale.
Tr(dc)	Triassic	Doi Chang Formation	Limestone, gray to light gray, finely crystalline, massive; limestone conglomerate with fossil bivalves, brachiopods and gastropods.
Tr(hh)	Triassic	Hong Hoi Formation	Silicified mudstone, gray to black, light brown to yellowish brown; intercalated with quartzite, light gray to dark gray, fine-grained; tuffaceous sandstone, gray to brownish gray, fine-to medium-grained, intercalated with shale, gray to dark gray; shale and siltstone, gray to greenish gray, with fossil *Halobia* sp., *Posidonia* sp., *Paratrachycerus* sp.
Tr(pk)	Triassic	Pha Khan Formation	Limestone, thin-beded to massive, oolith, oncolith, fossiliferous; interbedded with shale, sandstone, and mudstone, with fossils of *Daonella* sp. crinoid stems, bivalves, corals, and algaes.
Tr(pt)	Triassic	Phra That Formation	Lower part: Interbedded black shale, tuff and sandstone; Upper part: interbedded conglomerate, agglomerate, conglomeratic sandstone, tuff, sandstone, shale, mudstone, and siltstone, red, gray to dark gray and reddish brown; with limestone lens; locally developed phyllitic and slaty clevage with fossils *Claraia* sp., *Costatoria* sp., and other bivalves.
P3	Permian	Kiu Lom Formation, Ngao Group	Interbedded black shale, gray sandstone, dark gray mudstone, and gray limestone with chert nodules; intercalated with fossiliferous limestone and mudstone.
Igneous rock			
Bs	Pleistocene volcanic		Olivine basalt, gray to dark gray, vesicular texture, flow structure (Pahoehoe) with some volcanic bomb and scoria.
PTr(v)	Permo-Triassic volcanic		Volcanic rocks: rhyolite, andesite, flow and dike; agglomerate; volcanic conglomerate; rhyolitic tuff, and andesitic tuff.

Fig. 1 (continued)

solidation, and fossils, as described below from the lower to upper parts (Chaodumrong, 1985; Jitapankul *et al.*, 1985; Songtham *et al.*, 2005a and b; Silaratana *et al.*, 2004, 2004), as shown in Figs. 1, 2 and in the following descriptions:

2.1 Huai King Formation

It is the lowermost formation of the Tertiary succession that unconformably overlies the basement rock, the Lampang Group. The typical character is a fining upward sequence grading from conglomerate to mudstone or claystone on top. It is variegated in color, red, gray, green, yellow, blue and purple, common calcrete

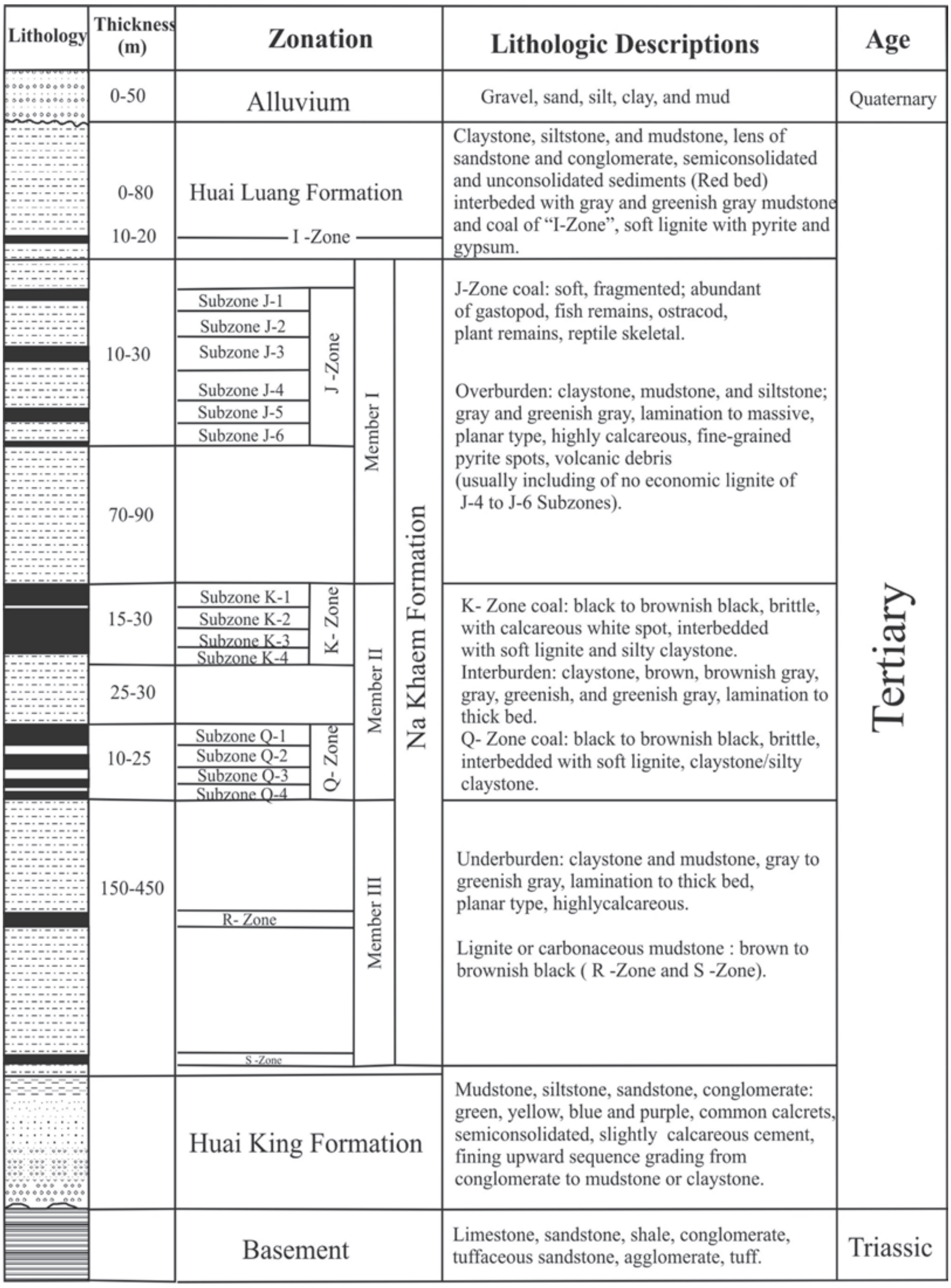

Fig. 2 Stratigraphic succession of Mae Moh coal mine (modified from Jitapankul, *et al.*, 1985).

in part, slightly calcareous cement, no macrofossils (except on the southern part found abundant *Viviparus* sp. in the lower portion of this formation). The thickness is varied from less than 15 meters on the border to 150 meters on the central part of the basin (Jitapankul *et al.*, 1985). The uppermost part of the formation is marked by a thin layer of coal named the O-Zone which occurs locally.

2.2 Na Khaem Formation

This Formation is the major coal deposit of the Mae Moh basin, and consists of semi-consolidated mudrock and five coal zones with varying thickness of 250 to 400 meters. Two of these coal zones are the major production of this mine. Jitapankul *et al.* (1985), Chaodamrong (1985), and Evans and Jitapankul (1990) divided this formation into three members as describe from lower part to the upper part:

Member III (Underburden) is a sequence of gray to greenish gray claystone and mudstone with a thin layer of coal of sub-bituminous rank, named the R-Zone. These beds are laminated to thick bed, planar type, highly calcareous, in the upper part with abundant gastropod beds, fish remains, ostracod, plant roots, intraformational conglomeratic texture and intermixed color texture near a coal seam or lignitic layer, burrow and boring, and load cast. At the Underburden / Q-Zone boundary downward is the ? *Paludina* Molluscan Zone of Songtham *et al.* (2005b). They suggested that the Mae Moh basin was a lake along a shallow shore in quiet conditions without any vegetation growing nearby. The thickness varies from 150 to 230 meters.

Member II is the most economically attractive coal sequence and is separated into three portions: Q-Zone, Interburden, and K-Zone.

The Q-Zone is a lower portion of coal that is black to brownish black and brittle, with abundant siliceous calcareous diatoms, the pyritized gastropod *Viviparussp.*, and Planorbidae and plant remains. It is interbedded with coal of sub-bituminous rank, with partings (about 30%) of light brown claystone/silty claystone. Technically the seams are divided into Q-1 to Q-4 with total thickness that vary from 25 to 30 meters. However, it separates to the north and south with thicker silty mudstone and changes laterally from coal layers to carbonaceous claystone and clay. The Planorbidae Molluscan Zone is located at the Underburden / Q coal boundary and the K-4 / K-3 boundary. Planorbidae are common in places, especially under the Q coal bed. This implies a swampy environment containing sparse to densely distributed vegetation (Songtham *et al.*, 2005a, b). A proboscidean fossil was discovered in the Q-2 Subzone (Permsook, 2007 personal communication).

The interburden is a sequence (10 to 30 meters thick) of brown, brownish gray, gray, green and greenish gray claystone that lies between the two major coal seams. These beds are laminated to thick-bedded, planar type, with common lignite flakes, fish remains, plant roots, rare ostracods, common intraformational conglomeratic texture on the lower part, common gastropods (*Viviparus* sp.), load cast, and abundant micro slip planes. This sequence is thicker in the east flank but thinner in the west flank of the main basin. The K-Zone is a sequence of black to brownish black, brittle, high calcareous coal in the upper part. Diatomite flourishes in the eastern part and can be used to separate the K-Zone into four layers, and there are common gastropods (*Planorbis* sp., *Mellanoides* sp., and *Viviparus* sp.) and rare fish remains and plant remains. This zone is interbedded with some coal of sub-bituminous rank with partings of light yellowish gray to gray silty claystone. The thickness varies from 10 to 30 meters. However, it is split in the north and south with thicker silty claystone partings and a lateral change to carbonaceous claystone and clay. The coal series are named K-1 to K-4. The K-4 Subzone of thin coal layer is the end of the Planorbidae Molluscan Zone. It was interpreted as a swamp deposit (Songtham *et al.*, 2005a, b). Between the K-3 and K-4 Subzones, the thick Viviparidae beds of *Bellamyawere* were deposited. The thickest layer is about 12 meters, deposited in the southwest margin of the coal pit. In K-3 and K-2 were found *Planorbis* sp. In K-2, Planobidae occurred widely associated with *Paludina* in carbonaceous claystone. All taxa are missing from the carbonaceous claystone K-1 where mastodont remaly, the skeletons of mastodons with tusks and molars were discovered in this K-Zone (Songtham *et al.*, 2005a, b). At the boundary of the K-1 Subzone and the overburden claystone indicated is *Melanosides* sp., cf. *M. tuberculata* Molluscan Zone. This zone is covered by the overburden claystone and J-Zone. The sulfur isotope of pyrite from the Q-zone, K-zone, and the lower part of J-zone indicate the source of sulfur was from organic sulfur inferring in the freshwater environment (Silaratana *et al.*, 2004).

Member I is the upper most of Na Khaem Formation. The coal beds of J-Zone are thin and not much economic. J-Zone consists of six sequences of gray and greenish gray claystone, mudstone, and occasional siltstone and coal (J-1 to J-6). These beds are laminated to massive, planar type, highly calcareous, with fine grain pyrite spots common in some part, and with abundant gastropods (*Mellanoides* sp., *Physa* sp., *Viviparus* sp.), fish remains, ostracod, plant remains, reptile skeletal elements, load structures, intraformational conglomeratic texture of pumice and volcanic debris, and intermixed color texture near coal seams or coal layers, and burrows and borings. The thickness is about 100 to 150 meters. The upper part of this zone consists of two thin argillaceous layers (thickness less than 2 meters) and 13 thin seams of coal within J-1 to J-6. The sulfur isotope from the middle part of the J-zone indicate a volcanic source, and then in the upper part the sulfur isotope may indicate a marine incursion or opening of the basin during coal deposition (Tankaya, 2001, Silaratana *et al.*, 2003; 2004).

2.3 Huai Luang Formation

This formation was call the "red bed" by Longworth-CMPS Engineers (1981), It is the uppermost formation which consists of red to brownish red, semi-consolidated and unconsolidated claystone, siltstone, and mudstone with some lenses of sandstone and conglomerate, with some gray layer interbeds in some parts. No macrofossils were found but abundant gypsum and pyrite, rare roots and flame structures exist. The thickness of this unit varies from less than 5 to 350 meters. It is thickest in the central part of the main and western sub-basin, thinning rapidly towards the eastern and western margins, where it is entirely absent from the stratigraphic sequence or only a few meters thick. The upper part of the "red bed" is the coal I-Zone with an abundance of *Margarya* mollusks, partly pyritizatized (Songtham *et al.*, 2005b), about 50-150 cm thick and found especially where the sequences are completely present. Longworth-CMPS Engineers (1981) concluded that their red/brown colors are likely to be due to the oxidation of fine-grained pyrite and hematite disseminated throughout certain layers within the formation. However, the results of sulfur isotope deduce from the red bed zone indicated a sulfur source from marine vaporized sulfate, but from pyrite in gastropod from the I-zone coal indicated a sulfur source from bacterial reduction of sulfate to sulfur (Silaratana *et al.*, 2003, 2004).

2.4 Coal Quality

The coal quality at Mae Moh is classified as low coal, not only low rank but also low quality, suitable only for feeding coal-fired power plants, due to a high ash and sulphur content. The proximate analysis of Mae Moh coal varies: moisture 15-33%, ash 11-34%, volatile matter 18-40%, and fixed carbon 6-36%. The sulphur content varies from 1-5% and calorific values between 1,750-4,250 cal/gm. Vitrinite reflectance is between 0.34-0.40 %Ro. Coal petrography indicates that a majority of macerals are densiniteand gelinite with an abundance of alginite, sporinite, liptodetrinite, but rare inertinite. The mineral matter shows an abundance of framboidal pyrite, especially in J coal zone.

2.5 Age of Mae Moh Basin

The age of the Mae Moh coal has been given by Ginsburg *et al.* (1983) to be Middle Miocene, deduced from its association with *Stegolophodon* sp. Later, paleomagnetic investigations of the Mae Moh basin (Benammi *et al.*, 2002), in the lower third of the Na Khaem Formation, and contining into the Huai Luang Formation showed that this sequence correlates on the geomagnetic polarity time scale from the C5ACn chron to C5An.2n chron, (Fig. 3), between 13.5 and 12.1 million years ago. The average sedimentation accumulation rate is about 17.5 cm/ka, and ages of 12.5 and 12.8 million years ago can be extrapolated to the fossiliferous levels (J-5 and K-1, K-2 coal)

3. Methodology

Viviparidae shells from Mae Moh Mine were selected from stratigraphic sequences in the open pit. The collected samples were from the under R-zone, Under Q-Zone and the thick *Bellemya* bed in the K-zone. The samples of living fresh water mollusks were collected from the Kew Lom Reservoir, about 40 km. north of Mae Moh. Shell samples were crushed into powder to determine the mineral contents in the shells using x-ray diffractometry. The isotopes $^{13}C/^{12}C$ and $^{18}O/^{16}O$ were analyzed from dissolved, crushed shells by mass spectroscopy at the Center for Geo-Environmental Science, Faculty of Engineering and Resource Science, Akita University, 1-1 Tegatagakuen, Akita 010-8502 Japan.

3.1 Mineral determination

The samples were crushed and underwent d-spacing determination using a Rigogu x-ray diffractometer. The conditions used Cu K ? radiation with voltage of 40 kv and 20 mA., slit width DS 1 RS 0.3 SS 1, scan speed 2 degree/min and step/sample 0.2 degree. The samples were scanned from 2 degree 2 to 60 degree 2. The diffraction peaks were converted to d-spacing and the mineral contents were identified by comparing the set of d-spacing with the ASTM XRD Powder Data File.

3.2 Isotopic analysis

Approximately 25 milligram of samples were weighed and placed at the bottom part of the two arms of the reactor tube. Two milliliters of phosphoric acid were placed in the side arms. The reactor tubes were vacuumed until no gas or vapor were left in the reactor before placing them to reach equilibrium at 25 °C water bath. The reactor tubes were tilted, allowing the acid to react with the samples and were left in the water bath for complete reaction. The carbon dioxide gas from the reaction was purified using the cryogenic process with the aid of liquid nitrogen (temperature -190 °C.), a mixture of dry ice and acetone (temperature -88 °C.), and a vacuum pump. The volume of gas obtained from the reaction of each sample was measured for its percentage yield. The purified carbon dioxide was kept in an airtight glass tube waiting for analyze by mass spectrometer for carbon and oxygen isotopes. The 12 Asc-2 L. No. 3 Carbon -oxygen isotopic standard was used to convert the isotopic ratio to PDB.

4. Results and Discussion

4.1 Mineral identification

The results of x-ray diffraction reveal the shells of Viviparidae in Mae Moh area, both fossils and Recent, are composed of only the single mineral aragonite.

4.2 Isotopic analysis

The isotopic results are shown in Table 1. The results reveal the Viviparidae shell ^{13}C values in Mae Moh Mine are between 3.52 - 6.92 ‰ PDB with the average of 5.52 ‰ PDB in the R-coal zone. In the Q-coal the ^{13}C value are between 4.17 - 5.77 ‰ PDB with the average of 5.12 ‰ PDB, which indicates a heavy isotope. In the K-coal zone the ^{13}C values are between 1.41 - 3.34 ‰ PDB with an average of 2.38 ‰ PDB. For oxygen isotopes the lower part of the basin showed the heavier isotope than the upper part, where the of ^{18}O values are between -3.15 and -5.10 ‰ PDB with an average of -

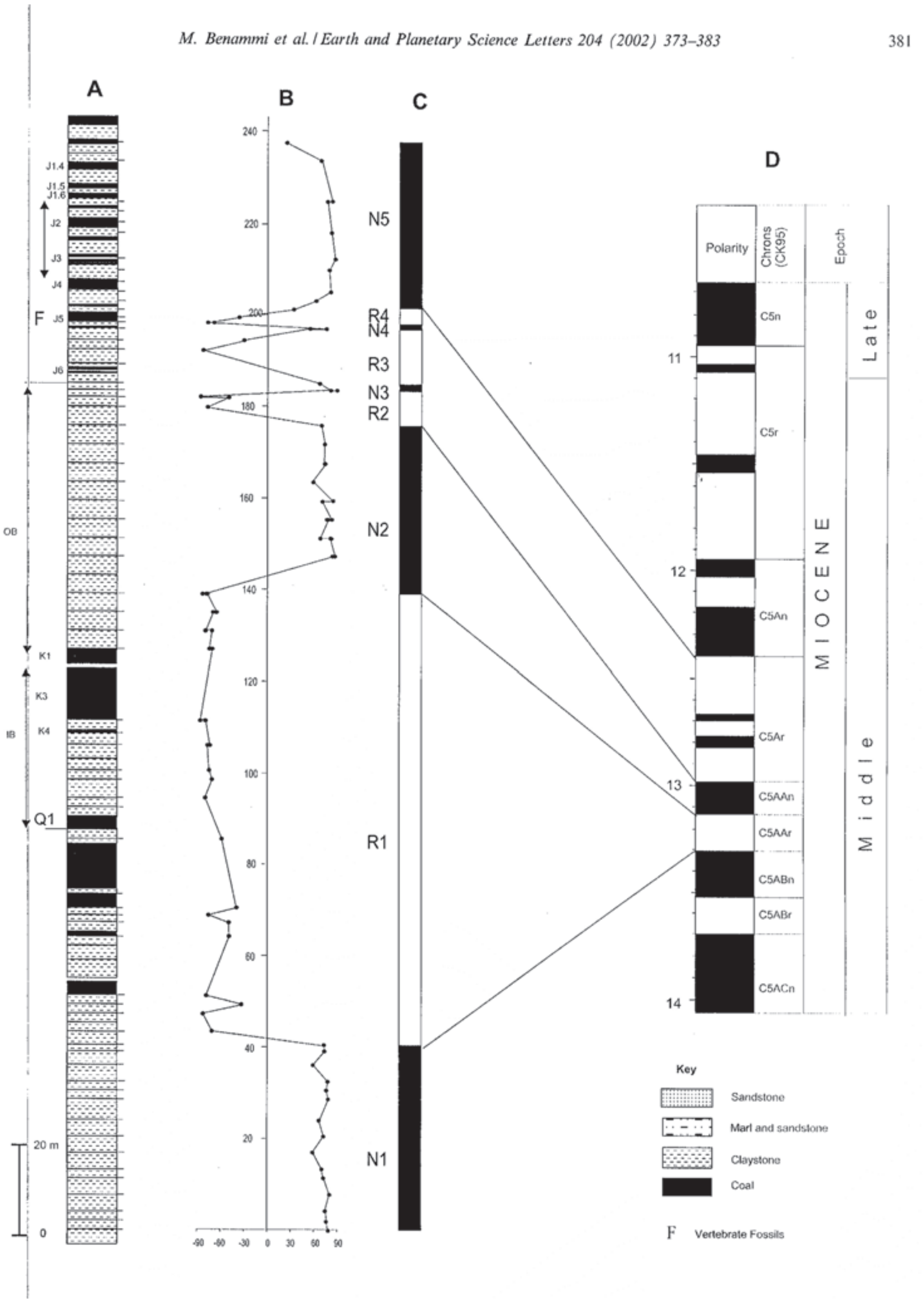

Fig. 3 Palaeomagnetic age dating of Mae Moh deposit (after Benammi *et al.*, 2002)

3.74 ‰ PDB in the R-coal zone, between -4.19 and -6.04 ‰ PDB with an average of -5.41 ‰ PDB in the Q-coal zone, and between -7.05 and -8.04 ‰ PDB with an average of -7.91 ‰ PDB in the K-coal zone. The isotope value of a Viviparidae shell collected from the Kew Lom reservoir in the Lampang area yielded ^{13}C values between -11.01 and -12.19 ‰ PDB with an average of -11.65 ‰ PDB and ^{18}O ‰ values between -6.64 and -7.04 ‰ PDB with an average of -6.76 ‰ PDB.

The isotopic results of Viviparidae fossil shells from the Mae Moh basin show a gradually change from the R-coal zone to the Q-, and the K-coal zone and significantly differ from Recent Viviparidae in the area. The heavy carbon isotope in the R-coal zone may imply a much cooler climate than during the Q- and K-coal zone deposition period when the area was much closer to the sea, especially when compared to the ^{13}C in the foraminifera (Srinivasan and Chaturvedi, 1990). Climatic conditions during Q- and K-coal zone deposition period were warmer and at a higher elevation or latitude than during deposition of the R-coal zone, as seen by the depletion of oxygen isotopes and enrichment of carbon isotopes (Andrusevich *et al.*, 2000). The changing records in the Mae Moh coal field are confirmed by temperate plant

Table 1 Result of carbon and oxygen isotopic analysis of Viviparidae from Mae Moh area.

Isotopic Analysis Viviparidae				
Analyze No.	**Sample Name**	**Type and locality**	**δ ^{13}C PDB**	**δ ^{18}O PDB**
		Mean of 12 Asc-2 L.No. 3 value **δ ^{13}C** measure =**33.88** **δ ^{18}O** measure = **21.75**	**0.72**	**-6.91**
Recent Viviparidae in Lampang Area				
7973	V1	*Filopaludina* sp. Kew Lom Dam Reservoir, Jae Hom, Lampang	**-11.01**	**-6.66**
7989	V111	F*ilopaludina* sp. Inner whirl, Kew Lom Dam Reservoir, Jae Hom, Lampang	**-12.19**	**-7.04**
7991	V112	*Filopaludina* sp. Middle whirl, Kew Lom Dam Reservoir, Jae Hom, Lampang	**-11.46**	**-6.76**
7992	V113	*Filopaludina* sp. Outer whirl, Kew Lom Dam Reservoir, Jae Hom, Lampang	**-11.92**	**-6.64**
		Average	**-11.65**	**-6.76**
Fossil Viviparidae in Mae Moh Mine, Lampang				
8055	V21	*Bellemya* sp. Mae Moh Mine K311-K4 Zone small and broken shell	**3.34**	**-7.05**
7976	V6	*Bellemya* sp., Mae Moh Mine, Lampang, K3	**1.41**	**-8.77**
		Average	**2.38**	**-7.91**
7977	V7	*Bellemya* sp. Mae Moh Mine, Lampang Under Q Zone	**5.77**	**-6.04**
7974	V4	*Bellemya* sp. Mae Moh Mine, Lampang Under Q Zone	**5.42**	**-4.19**
7975	V5	*Bellemya* sp. Mae Moh Mine, Lampang Under Q Zone	**4.17**	**-5.20**
		Average	**5.12**	**-5.14**
7988	V141	*Bellemya* sp., Mae Moh Mine R-Zone	**5.61**	**-6.52**
8034	V15	Bellemya sp., Mae Moh Mine R-Zone -0.5 m.	**4.37**	**-5.10**
8044	V16	*Bellemya* sp., Mae Moh Mine R-Zone-1m.	**3.52**	**-3.15**
8036	V17	*Bellemya* sp., Mae Moh Mine R-Zone-1m	**6.38**	**-3.07**
8037	V18	*Viviparus* sp.(small or Brit sp.) Mae Moh Mine R-Zone -1 m.	**6.92**	**-3.71**
8039	V20	*Viviparus* sp.R-Zone 10 m (Above the high wall)	**4.9**	**-3.68**
		Average	**5.22**	**-3.74**

fossils in other Oligocene to Lower Miocene basins in Northern Thailand. Palynofloras and fossil leaves have been recovered from the sedimentary sequences of the Na Hong coal mine in Mae Chaem, Chiang Mai, the Ban Pa Kha coal mine, and the Ban Pu and Na Klang coal mines in Li Basin, northern Thailand (Endo, 1963; 1964; 1966, Songtham *et al.* 2003; 2005a & b).

The basins and vicinity were occupied by warm temperate plant communities. The taxa include *Pinuspollenites*, *Alnipollenites verus*, *Momipites coryloides*, *Tsugaepollenites*, and *Inaperturopollenites*. The climate became warmer and wetter with time. This is indicated by the appearance of some pollen and spores, including *Lagerstroemia*, *Striatriletes*, *Perfotricolpites* *digitatus*, *Sporotrapoidites*, the algae *Pediastrum* and *Botryococcus*, and the fungus *Desmidiospora willoughbyi*. The age of the floras is Late Oligocene to Early Miocene. The change to a more tropical climate observed in Mae Moh stratigraphy, as recorded by the palynological assemblage (Meesuk,1986; Watanasak, 1988; Songtham *et al.*, 2005a, b) may have occurred during the Middle Miocene, as indicated by paleomagnetic age dating in the K- and Q-coal zone (Benammi *et al.*, 2002, 2003; Fig. 3).

The beginning of northern Thailand segment movement from the warm temperate area is not clearly understood. However, the age dating of the Mae Ping Fault zone at 29-31 Ma (Lacassin *et al.*, 1997; Ahrendt *et al.* 1993, 1994, 1997) may be the closest related events. The northward movement of the Australian-Indian plate and collision with the Eurasian plate, and the westward subduction of the Pacific plate, are suspected to be two major causes of the splitting and pushing of the northern Thailand segment southwestward along the Sakiang, Mae Ping and Red River Fault zones.

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タイ北部マエモー炭鉱産タニシ類化石の炭素・酸素同位体に記録された古生物地理と古気候の変化

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要　旨

タイ北部のマエモー炭鉱の R-, Q-, K-石炭帯から産出したタニシ類化石の炭素 13 ・酸素 18 の同位体分析を秋田大学で行った．その結果，下部層の方が重い炭素同位体比を示した．R-石炭帯の炭素同位体は 3.52-6.92 ‰ PDB で，Q-石炭帯では 4.17-5.77 ‰，K-石炭帯では 1.41-1.34 ‰ PDB 値を示した．酸素同位体比は下部層が上部層より重い値を示し，R 帯で-3.15 〜-5.10 ‰，Q 帯で-4.19 〜-6.04 ‰，さらに K 帯では-7.05 〜-8.04 ‰の範囲を示した．

これらのランパン地域のケウロム鉱床のタニシ類化石の同位体は炭素 δ^{13}C 値で-11.01 〜-12.19 ‰，δ^{18}O 値では 6.64 〜 7.04 ‰の範囲を示した．これらの結果，マエモー堆積盆では，R 帯から Q 帯，そして K 帯へと徐々に同位体が変化しており，さらに現在のタニシ類の同位体比とは明らかに異なる値である．この R 帯の重い炭素同位体比は，Q 帯や K 帯の堆積時より，より冷温であったことを示し，さらに当時の古地理は海に近い環境であったと考えられる．さらに Q 帯と K 帯の堆積時は，R 帯と比べて温暖化し，さらに地理的に高緯度化したか高度を増したことが考えられる．これらのマエモー炭鉱での古気候変化は，タイ北部の他の漸新統から下部中新統にかけての環境変化と同調的である．さらに，より温暖な熱帯への気候変化は K 帯と Q 帯の古地磁気層序年代から指示される中期中新世に生じている．これらの古環境変化の原因は，オーストラリアーインドプレートの北上に伴うユーラシアプレートとの衝突によって生じたものであると考えられる．

Plate 1 *Bellemya* sp.bed between K3-K4 coal zone, Southwest Pit, Mae Moh Mine. **a.** *Bellemya* sp. bed. **b.** Close up the *Bellemya* sp. shell.