TECHNICAL REPORT WC/98/33
Overseas Geology Series

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THE LAMPANG BASIN, CHANGWAT LAMPANG,
NORTHERN THAILAND

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Front cover illustration:
Top left: Graphical lithology of diatomite Section (4)
Top right: Team of DMR and BGS geologists logging diatomite Section (2)
Bottom right: Schematic illustration of the structure of amorphous hydrated silica.

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AN INVENTORY OF THE DIATOMITE DEPOSITS OF THE LAMPANG BASIN, CHANGWAT LAMPANG, NORTHERN THAILAND

S D J Inglethorpe¹, C Utha-aroon² & C Chanyavanich²

(1) Mineralogy & Petrology Group, British Geological Survey (BGS), Nottingham NG12 5GG, United Kingdom
(2) Department of Mineral Resources (DMR), Rama VI Road, Bangkok 10400, Thailand

SUMMARY

The Lampang Basin is a post-Oligocene, intermontane basin occupying an area of approximately 1000 km². Between 25-28 m of diatomite of the Ko Kha Formation, Mae Moh Group, is underlain by cyclothems of mudstone, oil shale and lignite of the Mae Sot Formation. Overlying are Quaternary to Recent fluvial gravels, sands and clays, generally capped by laterite. Dominant Melosira granulata and rare Navicula and Fragilaria diatom species of post-Miocene age indicate a freshwater, eutrophic, stagnant lacustrine environment. Fieldwork was carried out by a team of DMR and BGS geologists in 1996 with the aim of compiling an inventory of diatomite deposits in Changwat Lampang. Detailed lithological logs of major quarry sections were prepared. At each quarry, "spot" samples were collected at 0.5 m stratigraphic intervals and larger "laboratory" samples were also collected from the main diatomite beds. Diatomite quality was assessed mainly by physical analysis of the "spot" samples (block density, specific gravity, porosity, moisture content), supplemented by major-element chemical analysis of the larger "laboratory" samples. Results indicate that sedimentary features observed in the field (clay content, Fe-staining, discrete clay beds, bedding lamination, clay- and Fe-filled burrows etc.) are responsible for marked variations in physical and chemical properties. Because of this heterogeneity, it was possible to classify intervals within the diatomite sequence as either "high quality" or "low quality" on the basis of defined physical and chemical criteria.

The main objective of the diatomite inventory was to identify sources of diatomite in Thailand for use in the treatment of contaminated land. However, it is emphasised that the approach to the assessment of diatomite resources outlined in this report is generic and could be adopted by Geological Surveys/Mines Departments in other countries for primary classification of their diatomite deposits. BGS participation was funded by the United Kingdom's Department for International Development (DFID) under the Knowledge and Research (KaR) Programme project "Treatment of contaminated land using diatomite" (Project No R6488). For dissemination purposes, a summarized version of this report was presented at GEOTHAI '97, an international conference on the geology of Southeast Asia, and published in the conference proceedings (Inglethorpe et al., 1997)
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1. INTRODUCTION

1.1. Background

This report presents an inventory of the diatomite deposits of the Lampang Basin, Changwat Lampang, northern Thailand. Seven of the principal diatomite quarry sections in the region were visited by a party of DMR and BGS geologists during August 1996. Detailed lithological logs were prepared and the quality of these diatomite deposits classified on the basis of selected physical and chemical property measurements. Although fieldwork carried out in August 1996 was not exhaustive, it was targeted on the most promising prospects indicated by previous studies of diatomite in the region, which are also briefly reviewed here. BGS's participation was funded by the United Kingdom's Department for International Development (DFID) under the Knowledge and Research (KaR) Programme project “Treatment of contaminated land using diatomite” (Project No R6488).

1.2. Physiography and location of diatomite deposits

The Lampang Basin is located in Changwat Lampang, a province of northern Thailand approximately 450 km north of Bangkok. The part of the basin considered in this report is covered by four adjacent L7017 Series (Edition 1-RTSD 1969) 1:50 000-scale topographic map sheets (Table 1). Average height of the ground surface in the Lampang Basin is around 250 m above sea level. In the centre of the Lampang Basin, diatomite deposits form characteristic small, laterite-capped hills of 10-20 m elevation which protrude from surrounding low-lying rice fields. These hills typically support the growth of bushes and small trees. Along the margins of the basin, diatomite is usually exposed on downslopes underlying ridges of Quaternary river terrace gravel.

Table 1. 1:50 000-scale topographic map sheets for the field area.

<table>
<thead>
<tr>
<th>1:50 000 topographic sheet name</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphoe Hang Chat</td>
<td>4845 I</td>
</tr>
<tr>
<td>Changwat Lampang</td>
<td>4945 IV</td>
</tr>
<tr>
<td>Amphoe Mae Tha</td>
<td>4945 III</td>
</tr>
<tr>
<td>Amphoe Ko Kha</td>
<td>4845 II</td>
</tr>
</tbody>
</table>

The localities of diatomite deposits within the Lampang Basin are listed in Table 2. This was compiled mainly by reference to Kumanchan & Traiyan (1983), Kumanchan & Traiyan (1986) and Sripongpan (1985). The total area covered by these deposits is approximately 30 km². A location map for the three principal diatomite deposits identified by DMR (“Area A”, “Area B” and “Area C”) is shown in Figure 1.
Table 2. List of recorded diatomite deposits in the Lampang Basin, Changwat Lampang, Northern Thailand.

<table>
<thead>
<tr>
<th>Outcrop name</th>
<th>Alternative name</th>
<th>Cover</th>
<th>DMR designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Ban Mon Hin Kaew</td>
<td></td>
<td>Laterite/clay</td>
<td>Area A</td>
</tr>
<tr>
<td>(ii) Ban Pa Tan</td>
<td></td>
<td>Laterite/clay</td>
<td>Area A</td>
</tr>
<tr>
<td>(iii) Ban Pa Muang</td>
<td></td>
<td>Laterite/clay</td>
<td>Area A</td>
</tr>
<tr>
<td>(iv) Ban Nam Jo</td>
<td></td>
<td>Laterite/clay</td>
<td>Area A</td>
</tr>
<tr>
<td>(v) Ban Mon Saen Si</td>
<td></td>
<td>Laterite/clay</td>
<td>Area A</td>
</tr>
<tr>
<td>(vi) Ban Klui Phae</td>
<td></td>
<td>Laterite/clay</td>
<td>Area B</td>
</tr>
<tr>
<td>(vii) Ban Ouan, Tambon Mae Tha</td>
<td>Non Toy</td>
<td>Gravel/cobbles</td>
<td>Area C</td>
</tr>
<tr>
<td>(viii) Ban Pichai</td>
<td></td>
<td>Gravel ridge</td>
<td>Basin margin</td>
</tr>
<tr>
<td>(ix) Ban Huai Nam Khem</td>
<td>Kuai Nam Kam</td>
<td>Gravel ridge</td>
<td>Basin margin</td>
</tr>
<tr>
<td>(x) Ban Huai Nam Long</td>
<td></td>
<td>?Gravel ridge</td>
<td>?Basin margin</td>
</tr>
<tr>
<td>(xi) Ban Kui Lom</td>
<td></td>
<td>Gravel ridge</td>
<td>Basin margin</td>
</tr>
<tr>
<td>(xii) SSW of Nikhom Kui Lom</td>
<td></td>
<td>Gravel ridge</td>
<td>Basin margin</td>
</tr>
</tbody>
</table>

Area A
Outcrops (i)-(v) are located 4 km east of Amphoe Ko Kha and include parts of Ban Klui Mang, Tambon Klui Phae and Amphoe Muang. DMR have designated these outcrops “Area A”. 25 m of diatomite has been proved in “Area A”, occupying an area of around 25 km².

Area B
Outcrop (vi), Ban Klui Phae, is located 12 km south of Amphoe Muang along the Lampang-Mae Tha highway. DMR have designated Ban Klui Phae outcrop “Area B”. 28 m of diatomite has been proved in “Area B”, occupying an area of around 4 km².

Area C
Outcrop (vii) located at Ban Ouan, Tambon Mae Tha “close to the community of the Mae Tha compound” (Kumanchan & Traiyan, 1983). DMR have designated the Ban Ouan outcrop “Area C”. 13 m of diatomite has been proved in “Area C”, occupying an area of around 1.5 km².

Others
Outcrops (vii)-(xii) are located on the periphery of the Lampang Basin and are considered by DMR to be smaller deposits than those in areas A, B and C. Outcrop (viii), Ban Pichai, Tambon Pichai, is exposed on the eastern side of the Lampang-Chang Rai highway between km 5 and km 9. Outcrop (ix), Ban Huai Nam Khem, also located on the eastern side of the Lampang-Chang Rai, is exposed between km 20 and km 21. Outcrop (x), Ban Huai Nam Long, is located at Tambon Mae Than, south of Lampang town at about 49.5 km along the Lampang-Tak highway. Locality details for outcrops (xi) and outcrop (xii) are not available.

The localities of the seven quarry sections visited by the DMR/BGS project team during fieldwork in August 1996 are listed below. Quarry sections (2)-(7) are also shown on a map in Figure 1.
Section No (1)
GPS 47Q 05662 20312. This locality lies between Pichai outcrop (km 5-9) and Kuai Nam Khem outcrop (km 20-21) to the east of the Lampang-Chang Rai highway (location marked on Figure 2).

Section No (2)
GPS 47Q 05492 20114. North part of “Area A”, 2-3 km W of Ban Muang. 1 km NNE of DMR Shaft 1.

Section No (3)
GPS 47Q 05503 20066. Southern lobe of “Area A”, 1-1.5 km E of Ban Nom Cho. 4-5 km SSE of DMR Shaft 1.

Section No (4)
GPS 47Q 05499 20066. Southern lobe of “Area A”, 1 km E of Ban Nom Cho. 4-5 km SSE of DMR Shaft 1.

Section No (5)
GPS 47Q 05485 20087. Central part of “Area A”, 0.5-1 km W of Ban Mon Soan Si. 2.5-3 km S of DMR Shaft 1.

Section No (6)
GPS 47Q 05548 19994. 4.5 km S of “Area C” and DMR Shaft 3.

Section No (7)
GPS 47Q 05493 20129. Northern part of “Area A”, 3.5 km W of Ban Hua Fel. 2 km N of DMR Shaft 1.

At the time of the survey in August 1996, a number of the above quarries were active, although generally not worked during the wet season due to flooding. Extraction was relatively small-scale. Diatomite is dried, crushed, milled and bagged in 50 kg sacks to be sold as an ammonium sorbent for the fish farm market under brand names such as “Zeolite MT” and “Zeo 66”.

1.3. Previous investigations

The first geological investigation of the diatomite deposits of Changwat Lampang was carried out by Sresthaputra (Brown et al., 1951). An exposure of diatomite was discovered on the southern bank of the Mae Chang river (a tributary of the Mae Wang) in the Mae Nam Wang valley between Amphoe Hang Chat and Amphoe Mae Tha. Diatom species identified by Charaljavanaphet indicated a freshwater origin.

Pariwatawan (1962) conducted a more detailed investigation of diatomites in the Lampang region. The following five deposits were reported:

- Pi Chai, Amphoe Muang
- Huai Nam Khem, Amphoe Muang
- Nong Toi, Amphoe Mae Tha
- Kluai Phae, Amphoe Mae Tha
- Mon Hin Khew, Amphoe Ko Kha

Pariwatawan identified freshwater diatom species of Pliocene to Recent age. Gardner (1967) described a “widespread deposit” of white diatomite west of the Mae Moh valley. Thick beds of massive diatomite were separated by several thin layers of ochre-coloured diatomaceous clay. Piyasin (1972) noted an exposure of diatomite in the vicinity of Ban Pi Chi. Akutsu (1974) collected and identified diatoms from Mon Wang Ith, Lampang. Dominant Melosira granulata and rare Navicula and Fragilaria species
were recorded, the former indicating a freshwater, stagnant, eutrophic, lacustrine depositional environment. More recently, Owen (1996, pers. comm.) suggested that the predominant species present is actually *Aulacoseira*. Kumanchan (1979) reported bentonite interbedded with diatomite in the northern part of Amphoe Mae Tha.

A detailed investigation of the geology of the Lampang diatomite deposits was carried out by DMR in the early- to mid-1980s. During this period, DMR drilled 55 boreholes in the Lampang Basin to depths of up to 450 m on a 1 km grid covering around 120 square km. Where significant diatomite deposits were proven, six exploratory shafts (DMR Shafts P1-6) of 1.5 x 2.4 m dimensions were sunk to depths of up to 30 m. For Shafts P1, P2 and P3 (located in “Area A”, “Area B” and “Area C”, respectively), samples were collected at 0.3 m intervals for both physical (SG, bulk density, loose density, oil absorption etc.) and chemical analysis (principally SiO₂, Al₂O₃ and Fe₂O₃). The results of DMR’s field survey are described by Kumanchan & Traiyan (1986); these results were summarized and published externally (Kumanchan & Traiyan, 1983). Also, an MSc thesis by Sripongpan (1985) interpreted DMR’s field investigations in terms of lithostratigraphy and depositional environments.

1.4. Geology

The Lampang basin is a post-Oligocene, intermontane basin occupying an area of around 1000 km² and is one of 30 such basins in northern Thailand. The stratigraphy of the Lampang Basin is summarized in Table 3. A geological map of the basin is provided in Figure 2. The evolution of the Lampang Basin is summarized below.

The basement rocks of Permian and Triassic age are folded along the NE/SW trend of the Sukhothai fold belt. During the Himalayan Orogeny, a system of N-S trending normal faults developed under the tensional regime prevalent in northern Thailand. Consequently, a number of graben or half-graben controlled intermontane basins were formed and Tertiary deposits of considerable thickness were deposited, including Pliocene-age diatomite deposits of the Mae Mo Group. On the basis of the gravity survey data of Piyasin (1978), Sripongpan (1985) identified three discrete depositional areas (sub-basins) within the Lampang Basin: (1) The Lampang sub-basin; (2) Hang Chat sub-basin; and (3) Mae Tha sub-basin. The principal diatomite deposits, designated “Area A”, “Area B” and “Area C” by DMR, are within the Mae Tha sub-basin. The Mae Tha sub-basin is elongated along a NNE-SSW axis and bounded by a NEE-SWW anticline on its western flank. Sripongpan (1985) indicated that the geometry of the Area A, B and C diatomite deposits is generally lenticular. The elevation of the base of the Ko Kha Formation in “Area B” and “Area C” was found to differ from that of “Area A” by tens of metres.

During Pleistocene tectonism, Tertiary sediments within the Lampang Basin were uplifted, exposed sub-aerially and subjected to extensive fluvial erosion followed by deposition of Quaternary river terrace and channel deposits. The present-day outcrops of diatomite are isolated remnants of the Ko Kha Formation separated by these Quaternary fluvial sediments. In some examples (e.g. the western and southern perimeter of “Area A”), the boundaries of diatomite outcrops correspond closely to the present-day drainage pattern.
Table 3. Generalized stratigraphy of the Lampang Basin.

<table>
<thead>
<tr>
<th>Age</th>
<th>Symbol</th>
<th>Formation</th>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene to Recent</td>
<td>Qa</td>
<td>-</td>
<td>-</td>
<td>Alluvial clay, sand &amp; gravel</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Bs</td>
<td>-</td>
<td>-</td>
<td>Basalt, vesicular</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Qt</td>
<td>-</td>
<td>Mae Taeng</td>
<td>Higher and lower river terrace deposits, laterite</td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pliocene</td>
<td>Td</td>
<td>Ko Kha</td>
<td>Mae Mo</td>
<td>Diatomite, clayey, massive or laminated</td>
</tr>
<tr>
<td>Pliocene/Miocene</td>
<td>T</td>
<td>Mae Sot</td>
<td>Mae Mo</td>
<td>Cycles of mudstone, oil shale &amp; lignite</td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triassic (basement)</td>
<td>Tr hh</td>
<td>Hong Hoi</td>
<td>Lampang</td>
<td>Mudstone &amp; tuffaceous sandstone</td>
</tr>
<tr>
<td>Triassic (basement)</td>
<td>Tr pk</td>
<td>Pha Khan</td>
<td>Lampang</td>
<td>Limestone, thin-bedded to massive</td>
</tr>
<tr>
<td>Triassic (basement)</td>
<td>Tr pt</td>
<td>Phra That</td>
<td>Lampang</td>
<td>Shale, tuff, sandstone and conglomerate</td>
</tr>
<tr>
<td>Triassic (basement)</td>
<td>Tr gr</td>
<td>-</td>
<td>Lampang</td>
<td>Biotite granite &amp; biotite-hornblende granite</td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permain (basement)</td>
<td>PTr v</td>
<td>-</td>
<td>-</td>
<td>Rhyolite, tuff, andesite &amp; agglomerate</td>
</tr>
<tr>
<td>Carboniferous (basement)</td>
<td>C</td>
<td>-</td>
<td>-</td>
<td>Greywacke &amp; arkosic sandstone</td>
</tr>
<tr>
<td>Silurian - Devonian (basement)</td>
<td>SD</td>
<td>-</td>
<td>-</td>
<td>Quartzite &amp; phyllite</td>
</tr>
</tbody>
</table>
2. DIATOMITE INVENTORY

2.1. Diatomite assessment

Diatomite is a pale-coloured, soft light weight rock composed principally of the fossil remains of aquatic unicellular algae known as diatoms. Harries-Rees (1994) reviewed the current market conditions for diatomite and identified hazardous waste treatment as a potentially growing application. The properties of diatomite and its industrial use are described by Inglethorpe (1992), Breese (1994), Harben (1995) and Harben & Kuzvart (1996). Typical chemical and physical properties for diatomite sold commercially are listed in Table 4 below. Diatomite is characterized by white colour, high silica content, low specific gravity, low block density and high porosity.

Table 4. Selected chemical and physical specifications of diatomite sold commercially.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO2 (%)</td>
<td>89.70-91.20</td>
<td>85-94</td>
<td>84.50-91.20</td>
<td>/</td>
</tr>
<tr>
<td>Al2O3 (%)</td>
<td>0.62-3.72</td>
<td>1-7</td>
<td>0.62-3.72</td>
<td>/</td>
</tr>
<tr>
<td>Fe2O3 (%)</td>
<td>0.20-1.09</td>
<td>0.4-2.5</td>
<td>0.20-1.86</td>
<td>/</td>
</tr>
<tr>
<td>CaO (%)</td>
<td>0.19-3.00</td>
<td>0.3-1.0</td>
<td>0.19-3.00</td>
<td>/</td>
</tr>
<tr>
<td>SG</td>
<td>2</td>
<td>1.95</td>
<td>2.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Block density (g/cm3)</td>
<td>/</td>
<td>/</td>
<td>0.32-0.64</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Eardley-Wilmot (1928) advised that preliminary testing of diatomite should include estimation of colour, grit content, block density, porosity and chemical composition. Breese (1994) indicated that low block density distinguishes diatomite from other fine-grained sediments. Mathers et al. (1990) carried out detailed investigations of selected diatomite deposits in Costa Rica. Sections were logged in detail and changes in density (loose powder) and colour (% reflectivity at 4700 and 5800Å) were recorded down section. Percentage distributions of diatom flora were also reported. The methods used by the Instituto Tecnologico Geominera de Espana (ITGE) for the assessment of Spanish diatomite deposits were described by Regueiro et al. (1993). For resource assessment purposes, the quality of diatomite was defined by setting thresholds for (diatomaceous) silica content, density and moisture content (Table 5). Regueiro et al. (1993) indicated that ITGE's assessment criteria are well-suited to diatomite exploration in small basins.

Table 5. Quality specification used in the assessment of Spanish diatomite resources (Regueiro et al., 1993).

<table>
<thead>
<tr>
<th>Property</th>
<th>High quality</th>
<th>Medium quality</th>
<th>Low quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diatomaceous SiO2 (%)</td>
<td>&gt;70</td>
<td>70-30</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Block density (g/cm3)</td>
<td>&lt;0.7</td>
<td>0.7-2.0</td>
<td>&gt;2.0</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>&gt;12</td>
<td>6-12</td>
<td>&lt;6</td>
</tr>
</tbody>
</table>

2.2. Methodology

During the August 1996 fieldwork, the methodology used by the DMR/BGS team to assess Lampang diatomite deposits was essentially a synthesis and refinement of the procedures and working practices of both Mathers et al. and Regueiro et al. Quarry sections of diatomite were logged using standard logging sheets and the following information recorded:
Lithological description of each bed
- Dip measurement
- Bed thickness as measured normal to dip
- Sedimentary structures
- Fracturing and faulting
- Clay content
- Iron staining
- Wet and dry colour
- Hardness/consolidation/density
- Approximate particle-size and grit content, e.g. by glass plate/knife method

After logging, small rectangular monoliths ("spot samples") were collected from each lithology encountered, or at 0.5 m intervals in massive diatomite. The monoliths were sealed in plastic "securitainers" to prevent the loss of in-situ moisture. The following tests were subsequently carried out at the BGS's UK laboratories to monitor the variation of diatomite quality within each quarry section:

- Munsell colour
- Specific gravity (SG)
- Block density
- Calculated porosity
- Moisture content

In addition, larger 1 kg blocks ("laboratory samples") were collected, but only from the major diatomite beds in each logged section, and their major-element chemical composition determined at BGS by X-ray fluorescence spectrometry.

For quarry sections (1) to (7), graphical lithology and the results of physical and chemical analysis are shown in Figures 3-9, respectively. A brief commentary on the results obtained for each section is provided below.

### 2.3. Results

**Section No (1)**

GPS location: 47Q 05662 20312

Locality details: Intermediate between Pichai outcrops (km 5-9) and Kuai Nam Khem outcrop (km 20-21) to the east of the Lampang-Chang Rai highway. Quarry accessed by dirt track east of the main road.

Date logged: 22 August 1996

Depth (m): 9.08

Dip: Not measured

Graphical log: Figure 3

Comments: at this locality, diatomite is overlain by 1.75 m of lateritic soil. Elsewhere in this quarry, south of this section, diatomite is overlain uncomformably by Quaternary river terrace sands and gravels. The diatomite sequence is consistently low-grade. A particularly clayey, pale grey (Munsell 10YR 7/2), alumina-rich (18% Al₂O₃) diatomite of high block density (0.88-0.96 g/cm³) and low porosity (circa 60%) is apparent from 5.13-6.64 m. Overlying is a distinct pale brown colour (Munsell 10YR 8/3) Fe-stained diatomite between 4.25-5.13 m. The white colour (Munsell 10YR 8/2) diatomite between 3.56-4.06 m is probably of better quality, as indicated by lower block density (0.70-0.71 g/cm³) and higher porosity (71-72%). Well-preserved fossil leaves were observed in blocks from the base of the section.
Correlation: a tentative correlation is made with the interval in DMR shaft P1 below 25 m on the basis of a match in brown, yellow and grey Munsell colours present in Section No (1) but infrequent in other sections.

Section No (2)
GPS location: 47Q 05662 20312
Locality details: ?Ban Huai Lo. North part of “Area A”, 2-3 km west of Ban Muang, 1 km NNE of DMR Shaft 1.
Date logged: 23 August 1996
Depth (m): 2.22
Dip: Not measured
Graphical log: Figure 4

Comments: Only 2.22 m of the uppermost part of quarry section was logged at this locality. The lower part of section was inaccessible due to flooding. A relatively good quality massive diatomite from 1.12-1.49 m is indicated by good white colour, low block density (0.50-0.51 g/cm3), low SG (2.17-2.23), high porosity (77%), high silica (>75%), moderate alumina (10-12%) and low iron (<5%). The pinkish grey (Munsell 7.5YR 7/2) clay bed from 0.56-0.60 m is clearly marked by a specific gravity, block density and porosity response. A yellow (Munsell 10YR 7/6) Fe-rich, laminated diatomite unit is present between 0.00-0.56 m.

Correlation: None identified

Section No (3)
GPS location: 47Q 05503 20066
Locality details: Southern lobe of “Area A”, I-1.5 km east of Ban Nom Cho, 4-5 km SSE of DMR Shaft 1.
Date logged: 23 August 1996
Depth (m): 7.60
Dip: 14/044
Graphical log: Figure 5

Comments: This sequence is notable for the sedimentary lamination present throughout and for the frequent, often very strong, Fe-staining. The section was not easily accessible above 4.40 m and was not logged in detail, but strong Fe-staining was noted at 3.35 m. The sequence is capped by approximately 0.5 m of lateritic soil. The presence of Fe-stained intervals is clearly recorded by specific gravity, block density and porosity responses. The physical property results (block density = 0.77 g/cm3, porosity = 68%) and major-element composition (silica content =70-75%, iron content = c.5%) suggest that the white (Munsell 10YR 8/1), weakly-laminated diatomite between 4.78-5.10 m is of best quality.

Correlation: None identified

Section No (4)
GPS location: 47Q 05499 20066
Locality details: Southern lobe of “Area A”, 1 km east of Ban Nom Cho, 4-5 km SSE of DMR Shaft 1.
Date logged: 24 August 1996
Depth (m): 6.00
Dip: 38/024
Graphical log: Figure 6

Comments: Several small-scale, normal step faults were observed in the east quarry face adjacent to the lower part of this section. Generally, a relatively complex section due to presence of numerous clay beds and frequent Fe-staining, although diatomite below 3.94 m is more massive and homogeneous. The upper part of the quarry section
was inaccessible and therefore was not logged, although it was noted that the diatomite immediately overlying was fissile and laminated. Both block density and porosity show a clear response to the presence of clay beds and Fe-stained intervals. The massive diatomite between 3.94-4.30 m is of good quality as indicated by white colour, high silica (>75%), moderate alumina (10-12%), low iron (<5%) and favourable physical characteristics (SG= 2.21, block density = 0.65 g/cm³, porosity = 73%).

Correlation: A reasonable correlation is obtained between the clay beds logged in Section No (4) and those recorded between 6-12 m in DMR shaft P1 (see Figure 10).

Section No (5)
GPS location: 47Q 055485 20087
Locality details: Near Wat Mon Saen Si. Central part of “Area A”, 0.5-1 km west of Ban Mon Soan Si, 2.5-3 km south of DMR Shaft 1.
Date logged: 25 August 1996
Depth (m): 4.50 m
Dip: 12/063
Graphical log: Figure 7

Comments: Generally, a very homogeneous sequence, although thin clay beds and iron stained horizons are present throughout. Diatomite is relatively clayey as indicated by alumina content (>12% Al₂O₃) and pervasive pale grey colour (Munsell 10YR 7/1).

Correlation: None identified

Section No (6)
GPS location: 47Q 05548 19994
Locality details: 4.5 km south of “Area C” and DMR Shaft 3
Date logged: 26 August 1996
Depth (m): 4.50 m
Dip: Not measured
Graphical log: Figure 8

Comments: This section was considered the best prospect from field observations. Two thick beds of white massive diatomite of low density are present and Fe-staining is largely absent. Subsequent laboratory analyses indicate good quality diatomite between 1.30-2.70 m with high silica (>75%), moderate alumina (10-12%) and low iron (<5%) and promising physical characteristics (Specific gravity =2.25, block density = 0.55 g/cm³, porosity = 76%). SG, block density and porosity show a marked response to the three interbedded clay horizons.

Correlation: To some degree, Section No (6) can be correlated with the upper part of DMR shaft P3 between 5.00-9.50 m (see Figure 10). Silica content corresponds well and the lower part of both intervals are more clayey and Fe-rich.

Section No: (7)
GPS location: 47Q 05493 20129
Locality details: Northern part of “Area A”, 3.5 km west of Ban Hua Fel, 2 km north of DMR Shaft 1.
Date logged: 27 August 1996
Depth (m): 5.02 m
Dip: 5/180 approximately
Graphical log: Figure 9

Comments: Due to flooding, lower part of quarry section at this site was inaccessible. Therefore, only upper part of sequence was logged. In the field, under rainy conditions, diatomite appeared dense and clayey, and was weathered to small shaley
blocks. Laboratory analyses confirmed the relatively high block density and the presence of appreciable alumina and iron. Similar to Section No (5), consistent physical property values indicate that this section is homogeneous.

Correlation: None identified

3. DISCUSSION AND CONCLUSIONS

3.1. Origin of the diatomite deposits

In discussing the origin of the diatomite deposits in the Lampang Basin, Kumanchan & Traiyan (1986) suggested that devitrification of volcanic rocks within the pre-Tertiary basement provided the source of silica necessary for diatoms to flourish. However, if run-off or groundwater seepage from basement rocks did act as a source of silica, it might be expected that the strata immediately overlying the basement would be the most diatomaceous (i.e. the Mae Sot Formation) with an attenuation in diatom content over time, if factors such as the drainage, climatic conditions and clastic input to the basin remained equal. This is clearly not the case. Kumanchan (1979) reported the presence of bentonite beds within the diatomite sequence. Therefore, it is possible that the origin of the diatomite deposits may instead relate to silica enrichment of lake water by air-fall ash. This idea is supported by Ratanasthien (1992) who proposed that the presence of diatomite within the Mae Moh Basin was evidence of penecontemporaneous volcanism.

3.2. Sedimentary features

During the logging of the diatomite quarry sections (see Figures 3-9), the principal features observed in the field were:

- Clay content
- Fe-staining
- Presence of discrete clay beds
- Bedding lamination
- Clay- and Fe-filled rootlet structures

These features, responsible for the marked chemical and physical heterogeneity of the diatomite deposits of the Lampang Basin, are discussed in turn below.

Clay content

Previously, smectite, kaolinite and illite were identified from X-ray diffraction analysis of diatomite clay fractions (Kumanchan & Traiyan, 1986). This clay mineral assemblage is likely to have been derived from fine-grained clastic input.

Fe-staining

Evidence on the origin of the frequent Fe-staining observed is equivocal. Accumulation of Fe and Mn in eutrophic lake environments is reported in the literature (e.g. DeVitre et al., 1988) and may be associated with an annual period of deepwater anoxia. Much of the Fe observed within the diatomite sequence, especially the hard, nodular, Fe-cemented horizons, may represent such depositional accumulations, e.g. the so-called “rambutan” marker at circa 3.3 m in Section No (4). However, there is evidence that Fe has also been mobilised from the overlying laterite by percolating meteoric water. For example, in Section No (1), a network of Fe-filled fractures connected to the laterite overburden was observed. If transported by the movement of meteoric water through the diatomite, and in the absence of a chemical mechanism, Fe would be expected to precipitate when water movement is occluded. The Fe-staining observed immediately above discrete clay beds in several of the quarry sections supports this explanation.
DMR chemical analyses for trial shafts P1, P2, and P3 are summarized in Table 6. Assuming that: (1) SiO2 corresponds well with diatom content, (2) Fe2O3 is depositional in origin, and (3) Al2O3 essentially reflects clay mineral content (and therefore is a good indicator of clastic input), the chemical data in Table 6 indicates that drainage was more proximal to “Area B” and “Area A” than it was to “Area C”. This is consistent with drainage entering the basin from either the north or west.

### Bedding lamination

A pervasive bedding lamination was present throughout Section No (3). Similar varve-like accumulations of several millimetres thickness were noted by Breese (1994), each varve representing diatomite accumulation over a single annual cycle.

### Clay- and Fe-oxide-filled rootlet structures

The presence of clay- and Fe-oxide-filled rootlet structures is evidence that shallow water levels, or sub-aerial emergence, were experienced at least periodically.

#### 3.3. Correlation

For purposes of comparison and correlation, log details and laboratory results for DMR exploratory shafts P1, P2 and P3 (From “Area A”, “Area B” and “Area C”, respectively) have been summarized from Kumanchan & Traiyan (1986) and replotted here as Figure 10.

Correlation between diatomite sections described in this report and exploratory shafts P1, P2 and P3 has generally proved difficult. This is partly due to a paucity of marker beds and the fact that DMR logs were compiled at a different resolution. Discrete clay beds are likely to be most useful for correlation purposes, whereas Fe-cemented horizons are probably unreliable markers because of their uncertain origin. Apparently, some geophysical logging of the Ko Kha Formation was carried out although results were not reported (Kumanchan & Traiyan, 1986). Gamma logs, if available, would be useful for correlation purposes due to their sensitivity to clay content. More recently, Owen & Utha-aroon (1997) noted a stratigraphic zonation of diatom flora within the Ko Kha Formation of the Lampang basin. Four distinct diatom assemblages were identified:

- **Assemblage 1.** *Aulocoseira granulata, Aulocoseira sp. 1*
- **Assemblage 2.** *Aulocoseira goetzeana*
- **Assemblage 3.** *Aulocoseira granulata, var. valida*
- **Assemblage 4.** *Aulocoseira italic, var. bacilligara and var. tenuissima*

In diatomite sections, “Assemblage 1” is typically succeeded by “Assemblage 4,” or less commonly by “Assemblage 2.” Owen & Utha-aroon (1997) suggested that the Lampang Basin consisted of a number of isolated, discrete, shallow sub-basins developed within small-scale grabens. This concept is partly corroborated by the normal step faults and graben structures noted in Section No (3) and Section No (6), respectively. However, Owen & Utha-aroon (1997) also reported that, in parts of the diatomite sequence, the presence of “Assemblage 1” and the high degree of diatom breakages indicates a relatively deep water palaeolake in which strong bottom currents existed. This evidence, together with the close proximity of outcrops, their geographical extent (circa 30 km2) and thickness (up to 30 m), is more consistent with deposition in a single basin.
3.4. Classification of Lampang diatomite

In the diatomite deposits of the Lampang Basin, the presence of a number of sedimentary features (clay content, Fe-staining, discrete clay beds, bedding lamination, clay- and Fe-filled burrows etc.) results in marked fluctuations in chemical and physical properties. Because of this heterogeneity, it was possible to categorize intervals within the diatomite sequence as either “high quality” or “low quality.”

The properties of “high quality” diatomite strata were defined as follows:

**Lampang diatomite of “high quality”**
Good white colour
75-80% SiO₂
10-12% Al₂O₃
<5% Fe₂O₃
SG = 2.20-2.25
Block density =0.50-0.65 g/cm³
Porosity = 70-80%

“High quality” diatomite strata were identified at the following localities

- GPS 47Q 05492 20114, Section No (2), 1.12-1.94m interval
- GPS 47Q 05499 20066, Section No (4), 3.94-4.30 m interval
- GPS 47Q 05548 19994, Section No (6) 1.30-2.70 m interval

The physical and chemical properties of “high quality” Lampang diatomite still fail to meet the stringent chemical specifications required for diatomite sold commercially in Japan, North America and Europe. In particular, %SiO₂ falls about 8% short of typical commercial values, and %Al₂O₃ is at least 3-5% greater than would normally be acceptable. However, more encouragingly, “high quality” Lampang diatomite meets, or falls only slightly short of, chemical specifications for the filter-aid market (<1.5% Fe₂O₃ and < 1% CaO) (see Inglethorpe, 1992). Also, physical properties (colour, block density etc.) are generally comparable to those of diatomite sold commercially.

In contrast, the diatomite strata present throughout Sections No (1), (3), (5) and (7) are of “low quality,” as typified by the following properties:

**Lampang diatomite of “low quality”**
Grey, yellow or brown Munsell colours
<75% %SiO₂
>12% Al₂O₃ and/or >5% Fe₂O₃
SG >2.25
Block density >0.65 g/cm³
Porosity <70%

“Low quality” diatomite is generally rich in Al₂O₃ and/or Fe₂O₃ and therefore can be considered too impure to have commercial potential. However, a clayey, Fe-rich diatomite from Denmark termed “moler”, 68% SiO₂, 10% Al₂O₃ and 7% Fe₂O₃, (Harben & Kuzvart, 1996) is sold commercially, mainly as bricks for thermal insulation but also as pet litter and as an absorbent.
3.5. Summary

The main objective of this investigation was to identify a source of good quality diatomite in Thailand. Classification of the diatomite deposits of the Lampang Basin, using defined chemical and physical criteria, enabled identification of several such sources. Subsequent laboratory experiments and field trials will examine whether the diatomites described here are suitable for the treatment of contaminated land. In this report, a provisional correlation of the diatomite deposits of the Lampang Basin is proposed, mainly on the basis of their chemical stratigraphy (Figure 10). Examination of the stratigraphic zonation of diatom flora (see Owen & Utha-aroom, 1997), or re-examination of existing geophysical data, should enable a more definitive correlation.

4. ACKNOWLEDGEMENT

The authors fully acknowledge the co-operation and assistance of the Thai Department of Mineral Resources (DMR) in providing logistical support for the fieldwork in Changwat Lampang during August 1996. Khun Yupayong Tulayanon, Khun Narong Yuenyongghattaporn and Khun Khamrone Chaipinit of DMR are thanked for their dedicated and enthusiastic participation in the fieldwork. The maps in Figures 1 and 2 of this report were kindly prepared by Khun Surapong Mailarp of DMR's Economic Geology Division. Geologist Khamrone Pha-obphetch and his two assistants from the Lampang office of Clays & Minerals (Thailand) Ltd provided invaluable practical assistance during logging and sampling of quarry sections. BGS's participation was funded by the United Kingdom's Department for International Development (DfID) under the Knowledge and Research (KaR) Programme.

5. REFERENCES


Figure 1. Location of diatomite deposits in the central part of the Lampang Basin. Sections (2) to (7) logged and sampled during fieldwork in August 1996 are marked (Q2, Q3, Q4, Q5, Q6 and Q7). Section (1) is located on the north-east margin margin of the Lampang Basin and is marked on Figure 2. DMR exploratory shafts are also marked (P1, P2 and P3).
Figure 2. Geological map of the Lampang Basin and surrounding region. See Table 3 for explanation of map symbols.
Figure 3. Graphical lithology and results for Section (1).

<table>
<thead>
<tr>
<th>Graphic lithology</th>
<th>Lithological description</th>
<th>Specific gravity</th>
<th>Block density (g/cm³)</th>
<th>Porosity (%)</th>
<th>Moisture content (%)</th>
<th>Munsell colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOPSOIL: Laterite</td>
<td>Massive. Light grey brown. Silty texture. Grades into overlying latentic topsoil. Frequent Fe-oxide filled fractures connect to the overlying laterite.</td>
<td>2.00</td>
<td>0.90</td>
<td>35</td>
<td>0</td>
<td>White 10YR 8/2</td>
</tr>
<tr>
<td>-3</td>
<td>Fe-STAINED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>White 10YR 8/2</td>
</tr>
<tr>
<td></td>
<td>DIATOMITE Massive. Light grey brown. Silty texture.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>White 10YR 8/2</td>
</tr>
<tr>
<td>-4</td>
<td>Fe-STAINED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>White 10YR 8/2</td>
</tr>
<tr>
<td></td>
<td>DIATOMITE Massive. Light grey brown. Silty texture.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>White 10YR 8/2</td>
</tr>
<tr>
<td>-5</td>
<td>Fe-STAINED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very pale brown 10YR 8/3</td>
</tr>
<tr>
<td></td>
<td>DIATOMITE clayey: Massive. Medium brown to grey.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pale yellow 2.5Y 7/4-5.55 White 10YR 8/2</td>
</tr>
<tr>
<td>-6</td>
<td>Fe-STAINED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Light gray 10YR 7/2</td>
</tr>
<tr>
<td></td>
<td>DIATOMITE clayey: Massive. Medium brown to grey. &quot;Weak lamination at base.&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Light gray 10YR 7/2</td>
</tr>
<tr>
<td></td>
<td>DIATOMITE Massive. Light grey to brown. Blue-grey when weathered. Silty texture. Well preserved fossil leaves present.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>White 10YR 8/2</td>
</tr>
</tbody>
</table>

Figure 3. Graphical lithology and results for Section (1).
Figure 4. Graphical lithology and results for Section (2).

- **DIATOMITE Laminated:** Patchy, blocky, hard Fe-stained areas. Frequent clay-filled burrows.
- **CLAY:** Light grey to brown. Hard black nodules at 1.60m.
- **DIATOMITE:** Massive, buff to slightly pink, fine silty texture. Frequent clay-filled burrows. Siltified between 0.80-0.76m.

Yellow 10YR 7/6
Pinkish gray 7.5YR 7/2
Good white (10YR 8/1)
Yellow 2.5Y 8/4
<table>
<thead>
<tr>
<th>Graphic lithology</th>
<th>Lithological description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>CLAY</td>
</tr>
<tr>
<td>-1</td>
<td>DIATOMITE clayey</td>
</tr>
<tr>
<td>-2</td>
<td>CLAY</td>
</tr>
<tr>
<td>-4</td>
<td>CLAY: Medium grey to medium brown, slightly pink. Plastic.</td>
</tr>
<tr>
<td>-5</td>
<td>DIATOMITE clayey: Not logged in detail.</td>
</tr>
</tbody>
</table>

Figure 9. Graphical lithology and results for Section (7).
<table>
<thead>
<tr>
<th>Graphic lithology</th>
<th>Lithological description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>DIATOMITE: Massive. Off-white. Fossil rootlets present filled with Fe-oxide and clay, immediately below laminated diatomite.</td>
</tr>
<tr>
<td>-1</td>
<td>Fe-STAINED</td>
</tr>
<tr>
<td>-1</td>
<td>DIATOMITE: Massive.</td>
</tr>
<tr>
<td>-1</td>
<td>CLAY: Light grey, Plastic.</td>
</tr>
<tr>
<td>-1</td>
<td>Fe-STAINED</td>
</tr>
<tr>
<td>-2</td>
<td>CLAY: Light grey, Plastic.</td>
</tr>
<tr>
<td>-2</td>
<td>Fe-STAINED</td>
</tr>
<tr>
<td>-2</td>
<td>DIATOMITE: Massive.</td>
</tr>
<tr>
<td>-2</td>
<td>Fe-STAINED</td>
</tr>
<tr>
<td>-2</td>
<td>CLAY: Light grey, Plastic.</td>
</tr>
<tr>
<td>-2</td>
<td>DIATOMITE: Massive. Gradational contacts at top and base.</td>
</tr>
<tr>
<td>-3</td>
<td>Fe-STAINED</td>
</tr>
<tr>
<td>-3</td>
<td>DIATOMITE: Massive.</td>
</tr>
<tr>
<td>-3</td>
<td>Fe-STAINED</td>
</tr>
<tr>
<td>-3</td>
<td>CLAY: Light grey.</td>
</tr>
<tr>
<td>-3</td>
<td>Fe-STAINED: Hard, nodular &quot;rambutan&quot; marker.</td>
</tr>
<tr>
<td>-3</td>
<td>CLAY: Light grey.</td>
</tr>
<tr>
<td>-3</td>
<td>DIATOMITE: Massive.</td>
</tr>
<tr>
<td>-3</td>
<td>Fe-STAINED: Moderate only.</td>
</tr>
<tr>
<td>-4</td>
<td>DIATOMITE: Massive. Good white colour.</td>
</tr>
<tr>
<td>-5</td>
<td>Good white (10YR 8/1)</td>
</tr>
<tr>
<td>-6</td>
<td>Good white (10YR 8/1)</td>
</tr>
</tbody>
</table>

Figure 6. Graphical lithology and results for section (4).
### Figure 7. Graphical lithology and results for Section (5).

<table>
<thead>
<tr>
<th>Graphic lithology</th>
<th>Lithological description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>CLAY: Light grey.</td>
</tr>
<tr>
<td>-2</td>
<td>Fe-STAINED</td>
</tr>
<tr>
<td>-3</td>
<td>DIATOMITE: Massive. Light grey.</td>
</tr>
<tr>
<td>-4</td>
<td>Fe-STAINED</td>
</tr>
<tr>
<td></td>
<td>DIATOMITE clayey: Light grey laminated clay grades upwards into off white diatomite. Fe-stained. Brown clay-filled burrows or rootlets.</td>
</tr>
</tbody>
</table>
Figure 8. Graphical lithology and results for Section (6).
Figure 5. Graphical lithology and results for Section (3).
Figure 10. Schematic illustrating a tentative correlation between DMR exploratory shafts P1, P2, and P3 (Area A, Area B and Area C, respectively) and quarry sections (1), (4) and (6), on the basis of chemical stratigraphy (SiO2, Al2O3 and Fe2O3).