QUESNEL AREA - INDUSTRIAL MINERALS ASSESSMENT

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KEYWORDS: industrial minerals, Tertiary, diatomite, pozzolan, clay, pre-Miocene deep weathering, residual clays.

INTRODUCTION

A number of major diatomite occurrences are known in the Quesnel area of British Columbia. Several attempts have been made over the years to develop this resource, but there has been no lasting success. This project was undertaken to map the Tertiary sediments and volcanics of the area north and south of Quesnel and assess the industrial minerals potential of units in the area.

LOCATION AND ACCESS

Most of the area mapped is on the west side of the Fraser River, between the Cottonwood River in the north and Alexandria in the south. With few exceptions, accessibility is good over the existing system of farm and logging roads. The Narcosli Creek valley, adjacent slopes and tributary gullies are difficult to reach. Some areas along the Fraser River and Baker Creek have vertical cliffs tens of metres high that are impossible to reach and sample. The elevations of the map area are from 450 metres above sea level at the Fraser River banks to 900 metres on the plateau to the west.

GEOLOGICAL SETTING AND EXPOSURE

Rocks of Tertiary age in the Quesnel area are confined to a broad valley cut in pre-Tertiary bedrock (Lay, 1940). According to Rouse and Mathews (1979), the lower to mid-Tertiary volcanic and sedimentary strata were down faulted or infolded onto the older rocks and eroded. This was followed by deposition of the latest Lower to Middle Miocene Fraser Bend Formation and younger units. The upper Tertiary sediments and volcanics are horizontally bedded and probably not affected by regional faulting. The Tertiary strata were deeply eroded by both Pleistocene glaciation and subsequent fluvial processes. Figure 1 (following page) is a stratigraphic column for the area mapped. Figure 2 is a diagrammatic cross-section showing the structural relationships of the rock units.

Quaternary sediments cover most of the Tertiary rocks and a major Pleistocene valley to the east of the present Fraser River has been infilled with younger sediments. The Fraser River and its tributaries cut up to 450 metres of soft Tertiary sediments. The upper Miocene and later units were affected by numerous block landslides and mudflows in most of the map area. This completely distorts the original elevations of individual Tertiary units. The slides probably occurred in the Late Pleistocene or early Holocene and most seem to be stabilized.

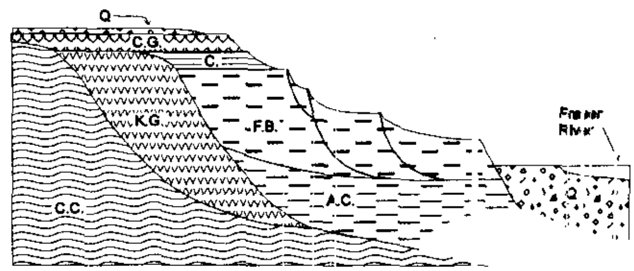
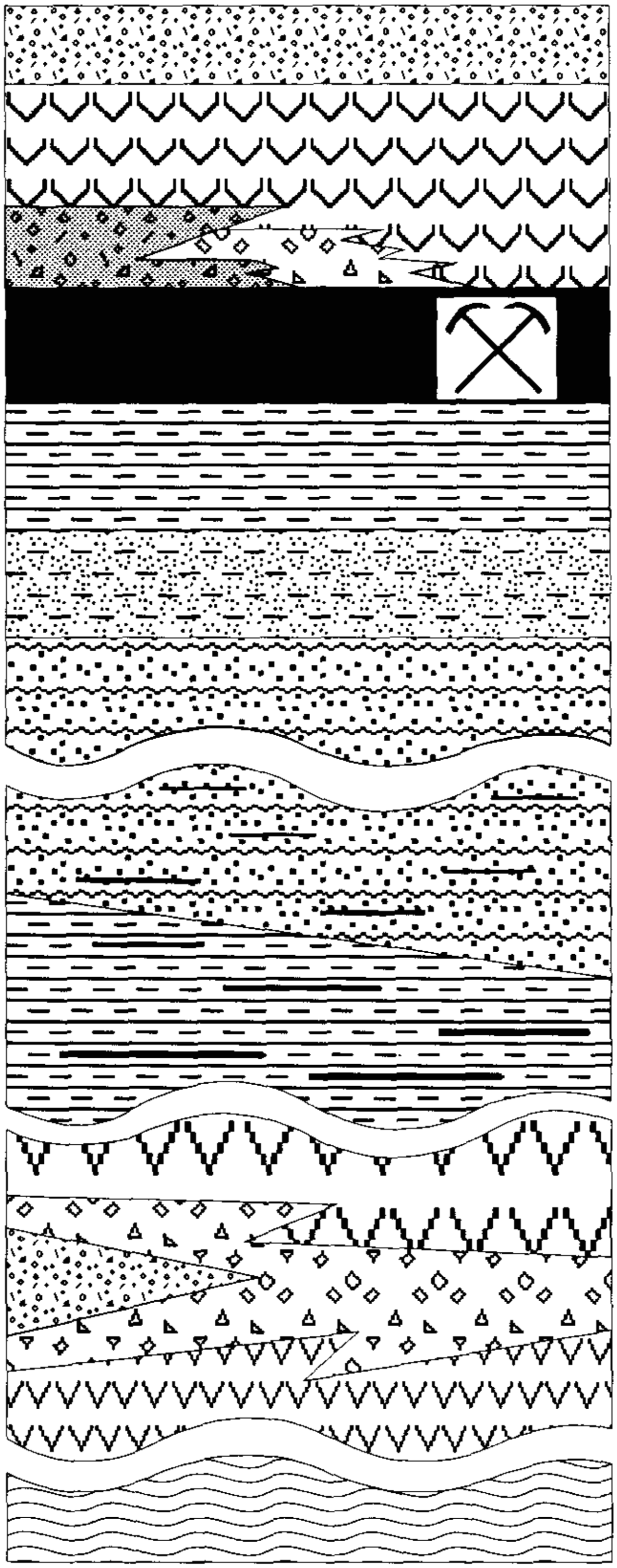


Figure 2. Diagrammatic structural cross-section of the rock units in the Quesnel area. C.C.: Cache Creek Group; A.C: *Australian Creek Formation*; F.B.: *Fraser Bend Formation*; C.: Crownite Formation; C.G.: Chilcotin Group equivalent volcanics; Q.: Quaternary sediments (modified from Rouse and Mathews, 1979).

STRATIGRAPHY

CACHE CREEK GROUP

Outcrops of the Mississippian to Triassic Cache Creek Group occur only in the northern part of the map area. Grey phyllite, locally with siliceous lenses, can be found along the Fraser River north of Big Bend and west of Quesnel along Baker Creek. Direct contact with younger units is exposed only in the upper parts of steep cliffs at Pinnacle Provincial Park, just west of Quesnel, where strongly weathered phyllites are overlain by a Chilcotin Group columnar basalt flow (Photo 1). Inaccessibility of this exposure prevents on-site examination of the unconformity. Although outcrops along the banks of both the Fraser River and Baker Creek are fresh, grey siliceous phyllites exposed in the upper parts of the slopes at Pinnacles Park are deeply weathered. This strongly weathered profile may be very thick, up to 100 vertical metres, along the slopes of Baker Creek. The phyllites have been altered to white or yellow clayey rock with illite the dominant clay mineral. Typical exposures are hoodoos and pinnacles; the result of recent erosion (Photo 2). A similar, deeply weathered profile in Cache Creek Group rocks is exposed on the west side of



Quaternary cover: Pleistocene till, glaciolacustrine and glaciofluvial sediments. Holocene sediments

Chilcotin Group: Upper Miocene flood basalt, black, vesicular and may be olivine phyric. May have yellowish palagonite breccia at the base of some flows. A thin, rusty, pebble to cobble

Crownite Formation: Late Middle Miocene lacustrine diatomite with variable clay matrix and clay interbeds. Typically buff-white and very recessive weathering. Host to two diatomite mines.

Fraser Bend Formation: Latest Lower to Middle Miocene sediments. Comprised of three subunits. Lower part is well sorted pebble (cobble) fluvial gravel. Clasts are primarilly quartzite with some chert. Matrix is sand. Central part is finer gravel, less well sorted and matrix is sand - silt. Upper part is interbedded fine clay, silt, sand and some fine gravel. The formation is typified by green, grey or blue-grey clay-rich layers. Lignite fragments are present in some of the sand and gravel beds.

Australian Creek Formation: Lower Oligocene sediments. Comprised of two subunits. The lower part consists mainly of massive, fissile clays and muds. Sand and pebble to cobble conglomerates are interspersed through the section. The upper part is dominated by conglomerates and pebble-rich sandstones. The matrix is clay rich. Conglomerate clasts are mostly volcanics with some phyllitic and granitic material. Lenses of lignite are common throughout the formation.

Kamloops Group Volcanics: An Eocene package of mixed dacitic to andesitic volcaniclastics and flows. The group consists mostly of black or grey breccia, lahars and lava. These units weather red, brown or tan. Breccias are commonly monolithologic or polymictic. Ash and tuff beds are rare but a distinctive manila-yellow lapilli tuff was traced over several kilometres.

Cache Creek Group: Mississippian to Triassic black phyllite and ribbon cherts. In some locations a thick, prominent white, yellow, rusty or buff residually

Figure 1. Stratigraphic column for the Quesnel area.

the Fraser River just upstream of the Cottonwood River canyon.

EOCENE VOLCANICS (KAMLOOPS GROUP EQUIVALENT)

Volcanic rocks of this unit outcrop mostly along Narcosli Creek and to the north and south of its confluence with the Fraser River. Grey, green and red-weathering andesite is most common with subordinate pink dacite. The rocks comprise a variety of lava flows, pyroclastic deposits and volcanic sediments. Autobreccias, monomictic and diamictic debris flows, and intercalated lava flows comprise most of the section (Photos 3 and 4). Irregular and discontinuous distribution of outcrops does not allow outlining the extent or subdivision map of individual rock types. However, scattered outcrops of a distinctive manila-yellow lapilli ash-tuff occur between south Quesnel and Narcosli Creek. Direct contact with either the lower or higher stratigraphic units has not been observed in the project area.

A zone of andesite pumicite is exposed in several places along the slopes on both sides of Narcosli Creek (Photo 5). The characteristic feature of this rock is a light bluish weathering of the exposed surface. This rock was successfully tested and marketed, by a local readi-mix company, as a natural pozzolan during the late 1970s.

AUSTRALIAN CREEK FORMATION

The Oligocene Australian Creek Formation comprises a broad range of strata from claystones through to unsorted boulder conglomerates. Seams of coal are common between clay and siltstone beds. The coal seams seen in outcrop are typically 5 to 20 centimetres thick and discontinuous. With few exceptions, beds with a high clay component exhibit a high swelling and shrinking fracture pattern in outcrop, indicating a montmorillonitic character (Photo 6).

Outcrops of the Australian Creek Formation are scattered, usually low along the Fraser River banks and many of its tributaries throughout the map area. The single, most complete section in the project area is the type section in Australian Creek, south of Quesnel. Measured dips suggest an anticlinal structure approximately parallel to the Fraser River with the crest on the east side of the river. Dips rarely exceed 20°. The angular unconformity with the overlying Fraser Bend Formation is exposed in several outcrops in the Big Bend area north of Quesnel (Photo 7) and on the west side of the Fraser River in Quesnel.

The Australian Creek Formation has been of economic interest because of the presence of coal seams (Photo 8). While no site in the map area reached the production stage, a number of exploration attempts have been reported. They indicate the thickness of coal seams reaches more than 10 metres locally, but the high ash

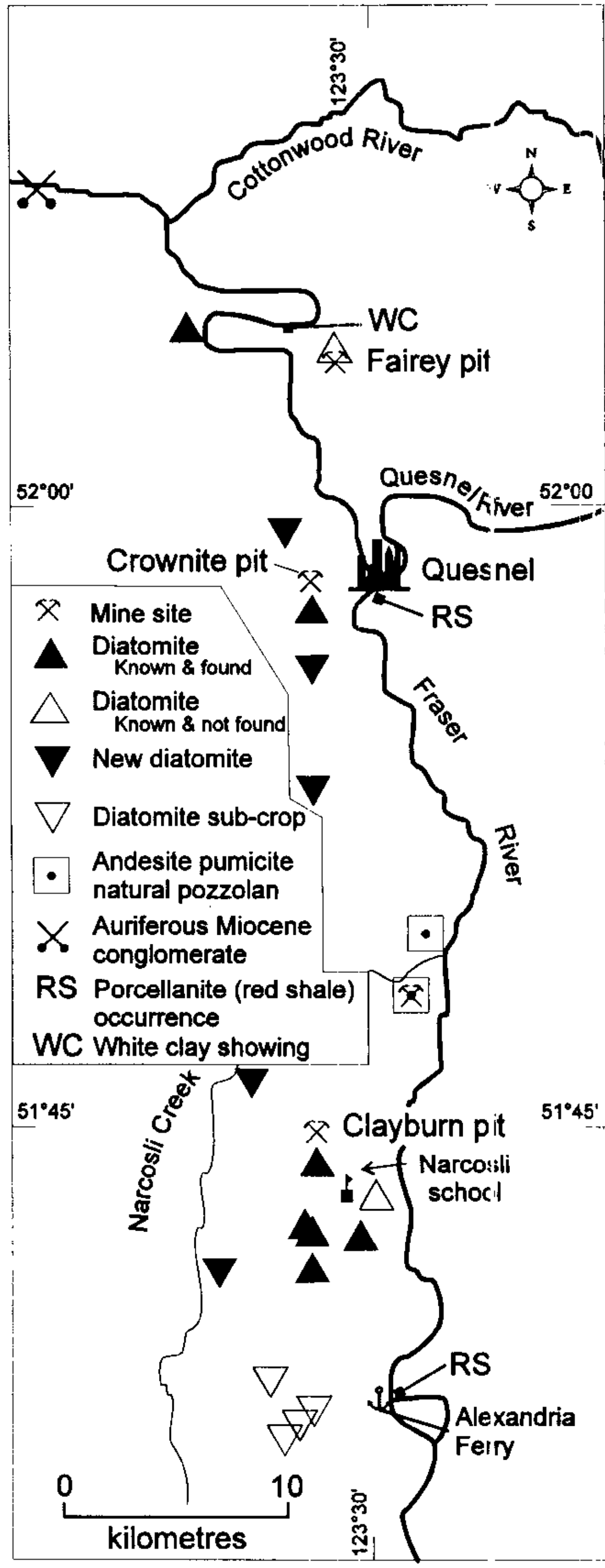


Figure 3. Location of mineral occurrences in the Quesnel map area.

content and low calorific value have discouraged further development. We identified coal outcrops along the

Photo 1. Columnar basalt flow on strongly weathered Cache Creek Group rocks.

Photo 2. Pinnacles in strongly weathered Cache Creek Group rocks.

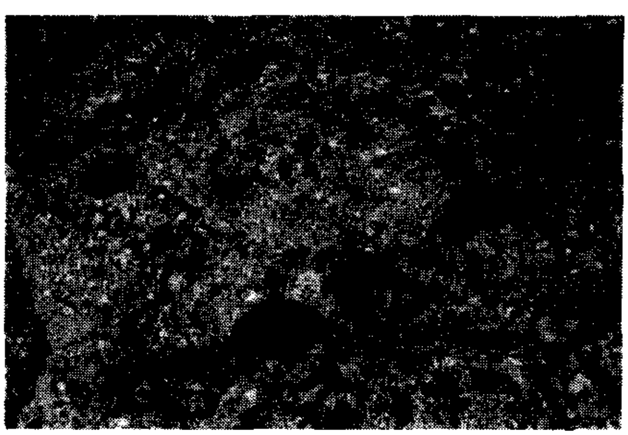


Photo 3. Agglomerate breccia north of Narcosli Creek. Clasts may reach 50 centimetres in diameter.

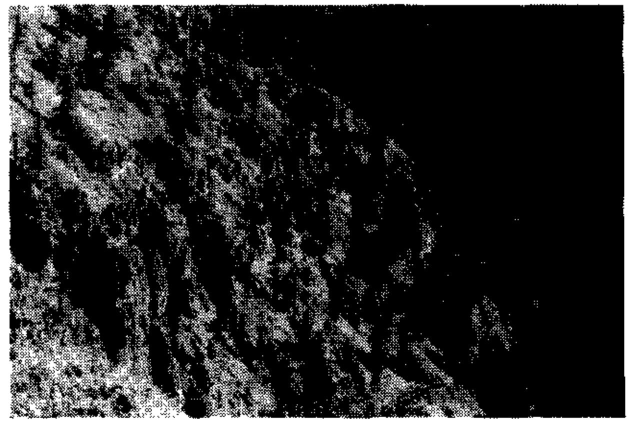


Photo 4. Agglomerate breccia outcrops, Narcosli Creek area.

Photo 5. Andesite pumicite, Narcosli Creek area.

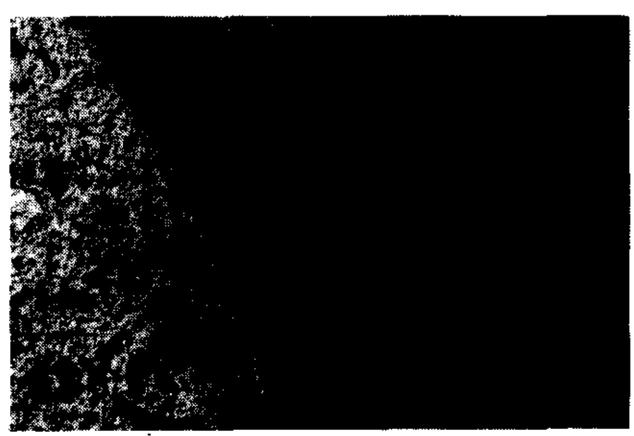


Photo 6. Australian Creek Formation clay bed with typical 'popcorn' surface indicating montmorillonitic composition.

whole area mapped from Big Bend to the old Alexandria ferry. Most are on the east bank of the river.

Outcrops of yellow to deep red porcellanite, locally called "red shale", the result of natural underground combustion of coal seams, occur at two locations (Figure 3, Photo 9). One site, on the south side of Quesnel city limits, has been called the Red Bluff and the rock was mined on a small scale for natural pozzolan and landscape aggregate. The other location, with no production so far, is located immediately south of the old Alexandria ferry crossing on the east side of the Fraser River.

FRASER BEND FORMATION

The Miocene Fraser Bend Formation is the best exposed unit in the map area. Its horizontal beds form the walls of steep ravines (Photo 10) and undercut banks along the Fraser River, particularly between the city of Quesnel and the Big Bend to the north. The Fraser Bend Formation overlies beds of the Australian Creek Formation on an angular unconformity (Photo 7). This contact was seen in several places on the west bank of the Fraser River between Big Bend and Quesnel.

The formation comprises a coarse, basal conglomerate with overlying conglomerate, sandstone and claystone and is up to 150 metres thick. The basal, pebble to cobble conglomerate is known to carry placer gold and has been mined underground for gold on both sides of the Fraser River, north of its confluence with the Cottonwood River. It is considered a source of gold in Fraser River terraces downstream (Levson and Giles, 1993).

Overlying the basal conglomerate are cobble to granule conglomerates, sandstones and a few silt and clay layers which comprise the lower half of the formation. The upper half is mostly clay and silt beds with scattered sandy or gravelly layers. These clays have a bright yellow or brown colour and, to a lesser degree, are pale green and grey. The principal clay mineral has been identified as illite (Rouse and Mathews, 1979). Close to the top of the Fraser Bend Formation, in the Big Bend area, our work has identified a layer of white clay 2 metres thick (Photo 11), possibly useable for ceramic manufacturing.

The contact of the Fraser Bend Formation with the overlying Crownite Formation is rarely exposed, but has been observed on the west side of the Fraser River in the Big Bend area and approximately 3 kilometres south of the Crownite pit.

CROWNITE FORMATION

The Middle to Upper Miocene Crownite Formation is a layer of diatomaceous earth up to 12 metres thick. While it is an extensive unit and outcrops are scattered over the whole map area (Figure 3), the upper or lower contacts are only exposed in a very few places. The diatomite was formed by the accumulation of the silica skeletons of freshwater diatoms living in an extensive, shallow lake. In some outcrops, diatomite caps the Tertiary sequence.

Diatomite is white, light beige or light grey and has a low density. The top and bottom few metres are bedded, a few centimetres thick; the central part is more massive with beds 20 to 30 centimetres thick. A brown, massive clayey layer has been noted in many exposures (Photo 13). In the two most complete sections, the Crownite pit and a ravine to the south, this bed, described as volcanic ash, is approximately at the middle of the diatomite sequence.

The diatomite strata have been affected by slumping of landslide blocks (Photos 12, 14) throughout the study area (described below). These multiple vertical displacements, expose outcrops of diatomaceous earth at many elevations, resulting in estimated thicknesses by some authors of 45 to 65 metres (140 to 200 feet; Godfrey, 1963). After the development of the Crownite pit west of Quesnel, which facilitated a better understanding of the depositional environment the thickness of diatomite beds in the Quesnel area, where no erosion has taken place, is estimated to be 12 metres. The beds are contaminated by clay minerals and devitrified volcanic ash. The reported Al_2O_3 contents from different sites and stratigraphic intervals are between 6.45% and 15.92% with Fe_2O_3 analyses between 3 and 4% (McCammon, 1960). Clay content and contamination by

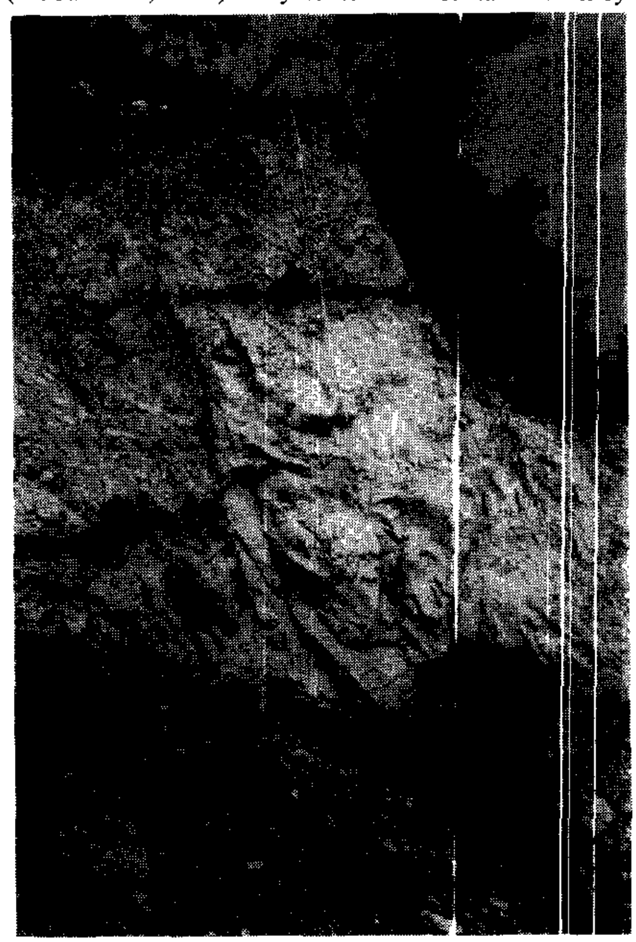


Photo 13. Crownite Formation diatomite. Note displacement of rusty (dark) volcanic ash layer

Photo 7. Australian Creek - Fraser Bend formations unconfomity, Big Bend area.

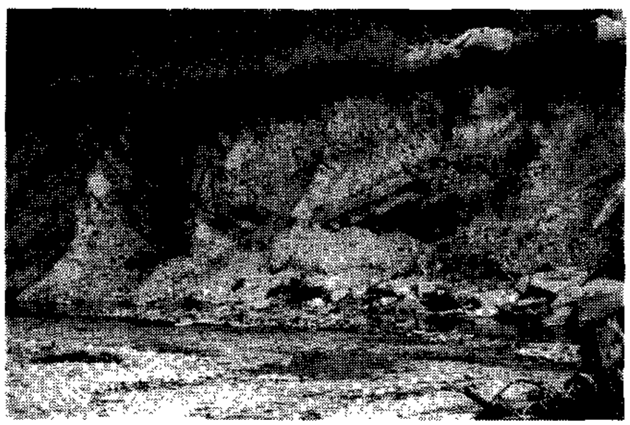


Photo 8. Australian Creek Formation with coal seam, Baker Creek, Quesnel.

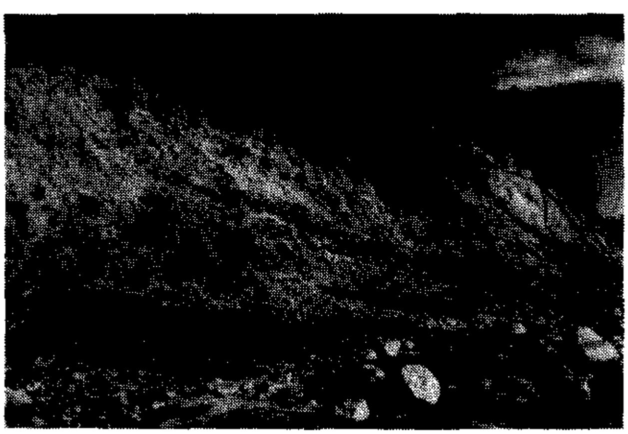


Photo 9. Partly burned coal seam with porcellanite zone, Australian Creek Formation near Alexandria ferry site.

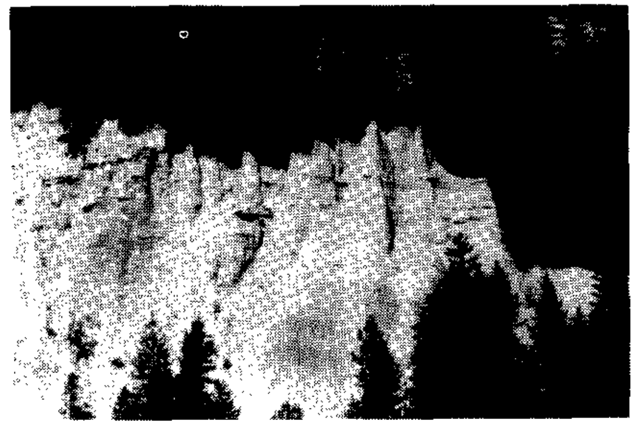


Photo 10. Hoodoo erosion of Fraser Bend Formation, Big Bend area.

Photo 11. Fraser Bend Formation, white ceramic clay bed, Big Bend area.

Photo 12. Diatomite bed in recent slump, Big Bend area.

Photo 14. Diatomite bed exposed by recent slumping in the Buck Ridge area.

Photo 15. Basalt flow filling channel in Crownite Formation diatomite, Clayburn pit.

Photo 16. Recent sliding in glaciolacustrine silts, 'Big Slide' near Big Bend.

iron oxides are the main obstacles for higher value end-uses of Quesnel diatomite.

MIOCENE PLATEAU BASALT (CHILCOTIN GROUP EQUIVALENT)

An Upper Miocene basalt flow forms a solid cap over the softer underlying strata from Quesnel to Alexandria and south. The flow typically forms massive, columnar jointed cliffs and is found on hilltops and the broad, high plateaus west of the Fraser River. The basalt is black, and vesicular and uniformly fine grained. The unit is 5 to 10 metres thick at Pinnacles Park (Photo 1) increasing to 20 metres in the Narcosli area and southwards. In some places, the lowermost part of the flow is pillowed with or without palagonite breccia.

At the Clayburn pit (Figure 3), a flow channel has a strongly brecciated base that deformed and, in part, incorporated diatomite (Photo 15). This clearly demonstrates that some parts of the flow extended into lakes, ponds and muds that were diatomite rich. A rusty brown, unsorted pebble conglomerate, a few metres thick, is exposed below the basalt and conformably overlies diatomite at the Crownite pit. Elsewhere, this conglomerate was seen at scattered outcrops in the map area and may be discontinuous in its areal extent.

QUATERNARY

Most of the map area is covered by a mantle of Quaternary deposits, locally very thick. The top of the plateau west of the Fraser River has a Pleistocene basal till cover with irregularly distributed patches of gravel on top of it. Grooves, drumlins and striae are very common and indicate movement of glacial ice from south to north (Tipper, 1971).

The lower elevations are covered by a variety of sediments with very complex relations. They include waterlain till, varved lacustrine sediments and multiple generations of meltwater channels and corresponding sediments. All these features are well exposed by the Holocene erosion of the Fraser River and its tributaries.

A deep, filled Pleistocene channel has been documented to the east of the present Fraser River course (Rouse and Mathews, 1979). The glaciolacustrine sediments are widespread and often disrupted by recent mud flows and landslides in the map area. The prominent example is the "Big Slide" (Photo 16), north of Quesnel, that has an active sliding area of approximately 4 square kilometres.

FAULTING AND LANDSLIDES IN TERTIARY ROCKS

Poor bedrock exposure in the whole map area makes identification of faults very difficult. With the exception of Eocene volcanics in the Narcosli Creek area, outcrops of pre-Miocene rocks are restricted to a few isolated places precluding the possibility of observing breaks in the continuity of specific units. Tipper (1959, 1960) in his mapping of the 93B and 93G map sheets identified

Photo 17. Block slumping in the Fraser Bend Formation, Big Bend area. White ceramic clay bed at top of the sequence.

only three faults within our map area. According to Rouse and Mathews (1979), there has been no faulting which would have affected the Miocene rocks in the area of our study. This contrasts with the frequent vertical displacement of Miocene units from the Fraser Bend sediments to the Chilcotin Group basalts, as observed throughout the project area. Such vertical displacements can be seen as far as 5 kilometres to the west of the Fraser River channel.

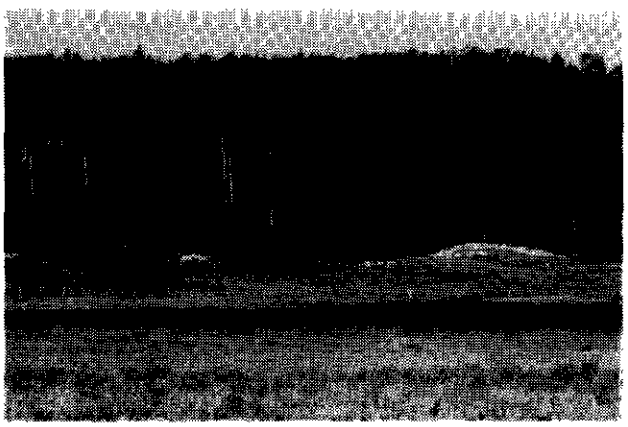


Photo 18. Drained and stabilized mudflow showing hummocky terrain with diatomite exposed (white), Buck Ridge area.

Block sliding is locally obvious. In the Big Bend area, for example, undercutting of near-vertical cliffs has triggered sliding of the Miocene sedimentary sequence towards the river in small blocks with many signs of recent movement. Such block slides are small in size, a few hundred metres in length, and extend only a few hundred metres from the river (Photo 17).

A much larger scale of sliding, however, has taken place in the southern part of the project area, between Narcosli Creek and the Fraser River. There, blocks, sometimes several kilometres long and up to 300 metres wide have slid towards the Fraser River and have vertical displacements of 1 or 2 to more than 10 metres. Quite often, a northerly trending, steeply dipping slide scar is the location of a poorly drained depression where the down-dropped block rests against the higher standing slice (Figure 4). Most of these slides seem to have stabilized and no indications of recent movements have been observed. However, the absence of fixed points may be obscuring the very slow process of creep which may be continuing. A geotechnical study in the urban area of Quesnel's east side, completed in 1977 and 1978, confirmed a relative displacement of 25 to 75 millimetres between two slide blocks over a period of one year. (M. Stepanek, personal communication, 1994).

It is not clear which beds within the Miocene sequence are the cause of block sliding. The failure surfaces are definitely deep seated and no seepage has been observed in the Miocene sequence. Although gravel and conglomerate beds, which could generate ground water pore pressures sufficient to trigger sliding, are common in the lower part of the Miocene Fraser Bend Formation, detachment may be occurring along the Oligocene-Miocene angular unconformity. This is in contrast to slides in the glaciolacustrine sediments, where numerous seepage horizons are clearly visible in exposed faces.

The lower benches of slide blocks are often covered by hummocky terrain, resulting from mudflows, now drained and stabilized (Photo 18). Such mudflows originated from upper blocks and led to the development of gullies that now drain the surrounding area (Figure 5).

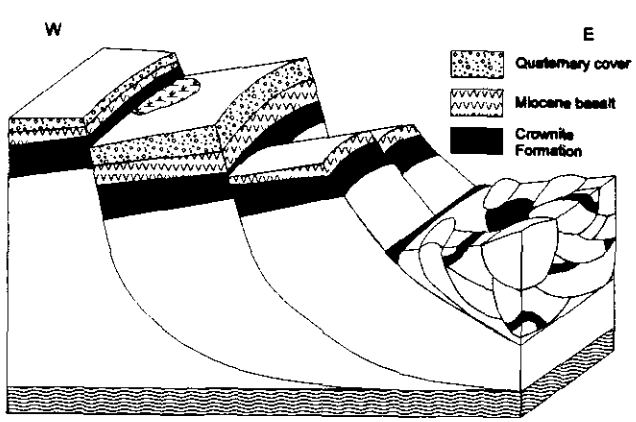


Figure 4. Block diagram of block sliding and slumping.

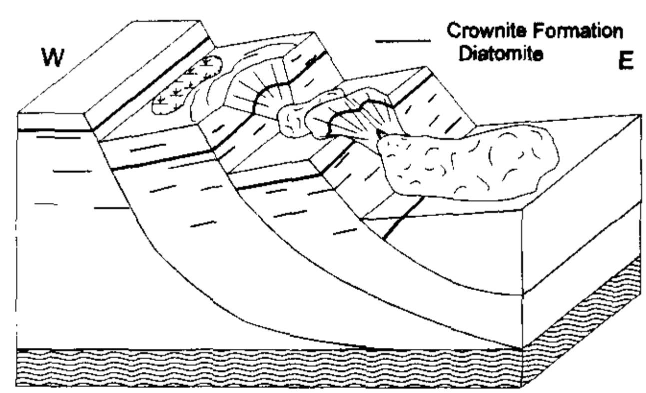


Figure 5. Block diagram of mud slides after block sliding. Short dashes are surface water seeps.

INDUSTRIAL MINERALS

DIATOMITE

Diatomite in the Quesnel area was first recognized by G.M. Dawson (1877), an early explorer. The first resource assessments were published by Reinecke (1920) and Eardley-Wilmot (1928). In 1937, Fairey and Cunliffe, a Vancouver company, started limited production of specialty ceramic products using diatomaceous earth from Quesnel as a raw material (Figure 3). This later expanded to manufacture of insulation brick and pozzolanic cement admixtures which continued until 1969. Its production came from Lot 6182 north of the Quesnel airport. Attempts to develop the resource in the Narcosli area (Buck Ridge) during the 1940s as a mineral filler or a filtration product did not succeed.

In 1963, Crownite Diatoms Ltd. of Calgary started to develop the deposit identified on Lot 906 on the west side of the Fraser River above Quesnel (Figure 3). The main products were anti-caking agents for fertilizer pellets and industrial and domestic absorbents. During intermittent operation and two ownership changes, considerable effort was made to develop a competitive, high value-added product by removing impurities like clay, calcium and magnesium sulphate from the crude diatomaceous earth. The process developed (Visman and Picard, 1969), for which Canadian Patent No. 890249 was issued in January 1972, succeeded in reducing clay contamination, measured by Al_2O_3 content, from 12.38% to only 4.8%. Such processing was never implemented in production and the operation on Lot 906 was permanently discontinued in 1984.

More recently, regular shipments of diatomite are made from a pit located on Lot 1615 at Buck Ridge, south of Quesnel, by Clayburn Industries Ltd. of Abbotsford, to manufacture insulation bricks.

NATURAL POZZOLAN

Three different types of pozzolanic materials from the Quesnel area have been marketed with some success. Both Fairey and Cunliffe and Crownite Diatoms Ltd. used the diatomaceous earth as pozzolan. Crownite Diatoms, however, recognized the pozzolan potential in ground porcellanite, also known locally as "red shale", the natural product of underground coal seam combustion. The pozzolan was used in a number of construction projects, particularly the W.A.C. Bennett dam (Carswell, 1966) on the Peace River at Hudson Hope. The porcellanite outcrops on the east bank of the Fraser River, south of the confluence with the Quesnel River and the site has been known as the Red Bluff. It is part of the Australian Creek Formation. Our mapping located a similar, previously unreported occurrence at the old Alexandria ferry site, on the east side of the river (Figure 3).

Another type of natural pozzolan was developed by a local company, Quesnel Red-Mix Cement Co. Ltd. Samples from a zone of andesite pumicite (Figure 3), part of the Eocene volcanic sequence in the Narcosli Creek area, were studied in 1964 by Construction Materials Section, Mines Branch, Department of Mines and Technical Surveys, in Ottawa (Malhotra and Zoldners, 1964). The results confirmed that the product meets ASTM and CSA specifications for pozzolan admixtures used in Portland cement. This type of natural pozzolan was produced from 1979 until 1984 and used in a number of construction projects in the Quesnel and Prince George areas.

CERAMIC CLAY

A bed of white clay, 2 metres thick, is exposed on the east side of the Fraser River, south of the Big Bend area (Figure 3). The clay bed is in the uppermost part of the Fraser Bend sediments and has been exposed by block slumping in a steep cliff above the river. The exposure is more than 100 metres long and the bed maintains its thickness and composition over the whole of the outcrop. The clay is being tested for its ceramic properties and preliminary results indicate it is probably suitable for stoneware type products (G Oprea, personal communication, 1984). The accessibility of this site is good and therefore the development potential, from a logistics point of view, is very good.

LANDSCAPE AGGREGATE

The porcellanite at Red Bluff has been used in the Quesnel area in limited amounts. The bright pink and red colours are very attractive and the material has been used for driveways, paths and roofing-chip aggregate

SUMMARY AND DISCUSSION

The 1994 map area is underlain by late Paleozoic phyllites of the Cache Creek Group and five Tertiary units: Eocene volcanics, Oligocene Australian Creek Formation, mid-Miocene Fraser Bend and Crownite Formation and Late Miocene plateau basalts. Mapping practically doubled the size and number of known diatomite occurrences. This observation suggests that the original diatomite deposition was widespread, extending from the northernmost showings in the Big Bend area all the way to the south near the old Alexandria ferry, probably in one large lake. The project also confirmed geologic resources of Eocene volcanics and burned, underground coal seams, porcellanite, of the Australian Creek Formation as sources of natural pozzolan

The deep weathering profile, several tens of metres, of Cache Creek rocks under the Miocene sediments, indicates a potential for residual clay deposits in similar geologic environments elsewhere. Beds of white clay suitable for ceramic wares may provide raw material for a local cottage industry. Similar clays are presently imported to British Columbia from Alberta and California.

ACKNOWLEDGMENTS

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REFERENCES

Carswell, H. A. (1966): Crownite Diatoms Ltd.; unpublished letter, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Mineral Deposits File.

Dawson, G.M. (1877): Report on Explorations in British Columbia; *Geological Survey of Canada*, Reports on Explorations and Surveys of 1875-76, pages 233-280.

Eardley-Wilmot, V. L. (1928): Diatomite, Its Occurrence, Preparation and Uses; *Canada Mines Branch*, Publication 691, 182 pages.

Godfrey, J. D. (1963): Diatomaceous Earth Deposits in the Quesnel District, British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Mineral Deposits File, private report, 24 pages.

Lay, D. (1940): Fraser River Tertiary Drainage History in Relation to Placer Gold Deposits; *B.C. Ministry of Mines*, Bulletin 3, 30 pages.

Levson, V. M. and Giles, T. R. (1993): Geology of Tertiary and Quaternary Gold-bearing Placers in the Cariboo Region, British Columbia (93A,B,G,H); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 89, 202 pages.

Malhotra, V. M. and Zoldners, N. G. (1964): Evaluation of Pozzolanic Properties of a Pumicite from Quesnel; *Department of Mines and Technical Surveys*, Canada Mines Branch Investigation Report R64-37, 8 pages.

McCammon, J. W. (1960): Diatomite; *in* Report of the Minister of Mines 1959, *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages 156-166.

Reinecke, L. (1920): Mineral Deposits between Lillooet and Prince George, British Columbia; *Geological Survey of Canada*, Memoir 118, 129 pages.

Rouse, G. E. and Mathews, W. H. (1979): Tertiary Geology and Palynology of the Quesnel Area, British Columbia; *Bulletin of Canadian Petroleum Geology*, Volume 27, No. 4, pages 418-445

Tipper, H.W. (1959): Geology of the Quesnel Area, Cariboo District, British Columbia; *Geological Survey of Canada*, Map 12-1959

Tipper, H.W. (1960): Geology of the Prince George Area, Cariboo District, British Columbia; *Geological Survey of Canada*, Map 49-1960

Tipper, H. W. (1971): Glacial Geomorphology and Pleistocene History of Central British Columbia; *Geological Survey of Canada*, Bulletin 196, 89 pages.

Visman, J., and Picard, J. L. (1969): Process for Beneficiation of Diatomite Ore; Canadian Patent Number 890249, 19 pages.