THE UPPER CRETACEOUS OIL BEARING SEDIMENTARY ROCKS OF HOKKAIDO, JAPAN

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With 9 Text-figures

CONTENTS

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ABSTRACT

The upper Cretaceous sediments of the Hetonai district, Iburi, Hokkaido, are discussed. Of those upper Cretaceous sediments, the Hetonai series, an upper Senonian formation, which is the only petroliferous sediment of the Mesozoic age in Hokkaido, is described. The Poronai formation, a lower Miocene formation, is also described. The petrographical characters of the sediments suggest to us the conditions of the sedimentation of the sediments. The structural history is discussed.

INTRODUCTION

The area discussed in this report lies at the eastern end of the Iburi (膽振) province, Hokkaido. Sapporo City is about 128 kilometers north-west of this region. The Hokkaido Railroad Company Line runs southeastward from Sapporo City and thence northward to Hetonai (邊富内) Town by way of Mu-kawa (鵡川) as is shown in figure 1.

The Mesozoic formations in Hokkaido, in which oil might have originated or from which oil might have migrated, have been previously reported briefly by other authors[(1)]. But this paper gives details, stratigraphically and lithologically, regarding the oil bearing sediments of Mesozoic age in Iburi, Hokkaido, as this is a new locality of the petroliferous rocks in the Iburi province. The formation is not so important economically as that of the Cretaceous sediments (Chico formation) of the Coalinga oil field[(2)] in California, and that

(1) Y. Okamura: Geology of Saru-gawa District, Hidaka. Mineral Survey Report No. 4, 1911 (Japanese). Geology of North Central part of Hokkaido. Mineral Survey Report. No. 11, 1912 (Japanese).
K. Titani: Oil Fields of Japan, 1927 (Japanese).

(2) Ralph Arnold and Robert Anderson: Geology and Oil Resources of the Coalinga District, California. Bull. 398, U. S. Geol. Survey, 1910.

of the Jurassic formation(1) in Alaska, which may be the only pre-Tertiary oil bearing productive formations in the North American Pacific Coast. Generally, the pre-Tertiary formations developed in the northern Pacific coastal regions do not play so economically important a rôle in producing oil as the Tertiary formations do. But it is an interesting problem to study the geological occurrence of the oil bearing pre-Tertiary sediments from the stand point of the sedimentation of the organic rocks in which oil might have originated in the region. It may be also an interesting point, from the economical standpoint, that on the American side of the Pacific Coast, oil occurs from the sediments of the Cretaceous up to Pliocene age, while on the Asiatic side it occurs only from the Neogene Tertiary sediments, and coal comes from the Paleogene Tertiary and the Cretaceous sediments instead of oil. Therefore it is a remarkable point that the Cretaceous sediments in which oil might have originated are found on the Asiatic side of the Pacific coast, although it may be of no economic importance.

The Cretaceous sediments in this region are also tentatively correlated on the basis of palaeontologic, stratigraphic, and lithologic similarity, with those of Saghalin Island and other localities of Hokkaido described by S. SHIMIZU(2), and H. YABE(3).

ACKNOWLEDGMENTS

The present district was selected for the field work of the geological students of the Faculty of Science, Hokkaido Imperial University, Summer, 1930. During the field seasons the careful and accurate observations of the students were material aids to the completion of this report. To Professor TAKUMI NAGAO the present writers are much indebted for the determination of the fossils. TAKEO WATANABE, a geological assistant of the Faculty, also assisted the petrographical work on the igneous rocks.

(1) GEORGE C. MARTIN: Preliminary Report on Petroleum in Alaska. Bull. 719, U. S. Geol. Survey, 1921.
W. R. SMITH: Mineral Resources of Alaska. Bull. 773, U. S. Geol. Survey, 1925.

(2) S. SHIMIZU: Cretaceous Deposits of North and South Saghalin. Annual Report of the Work of Saito-Ho-on Kai, No. 5, Sendai, Japan, 1929.

(3) H. YABE: Cretaceous Stratigraphy of the Japanese Islands. Science Reports, Tohoku Imperial University, Sendai, Second series (Geology), Vol. XI, No. 1, 1927.

STRATIGRAPHY

GENERAL CHARACTER

The rocks of the Hetonai district fall into three classes—a metamorphic complex, which is commonly referred to as the basement complex of the Hokkaido sedimentaries, a series of sedimentary rocks, and an igneous intrusive rock. In this report the many different kinds of rocks that compose the basement complex have not been separated, as their separation is not important in relation to the occurrence of petroleum in this region. The metamorphic rocks are all of Palaeozoic age and have been intruded by serpentine. The sedimentary rocks range in age from Upper Cretaceous to Recent and comprise the Upper Ammonite bed (Turonian and lower Senonian), Hetonai series (upper Senonian), Poronai series (lower Miocene), and river terrace deposits and valley alluvium (Pleistocene and Recent). In lithology they show a great diversity in types of shale, sandstone, and conglomerate. The igneous rock may be of post-Cretaceous age and has intruded the Upper Ammoniate bed. It comprises only basalt.

The Cretaceous and Tetiary sediments are summarised in the following geological columnar section (Figure 2).

CRETACEOUS SYSTEM

Upper Ammonite Bed

GENERAL FEATURES

The Upper Ammonite bed is the basal bed of the Cretaceous sediments of the present district. The Upper Ammonite bed exposed within the area mapped, belongs to the formation of Turonian and lower Senonian age of the Cretaceous Period, and consists mainly of two members—a massive soft black shale and a tufaceous sandstone. The shaly member occupies a wide area in the central part of the field forming from its ease of erosion a low land or a broad valley. Its outcrop forms structually a steep reversed monocline, plunging steeply to the east. The tufaceous sandstone developed at the upper part of the Upper Ammonite bed is also massive and white in colour with pyroclastic materials. Some differences in topography are noticeable in these two members; these are probably due to a difference in composition of the rocks.

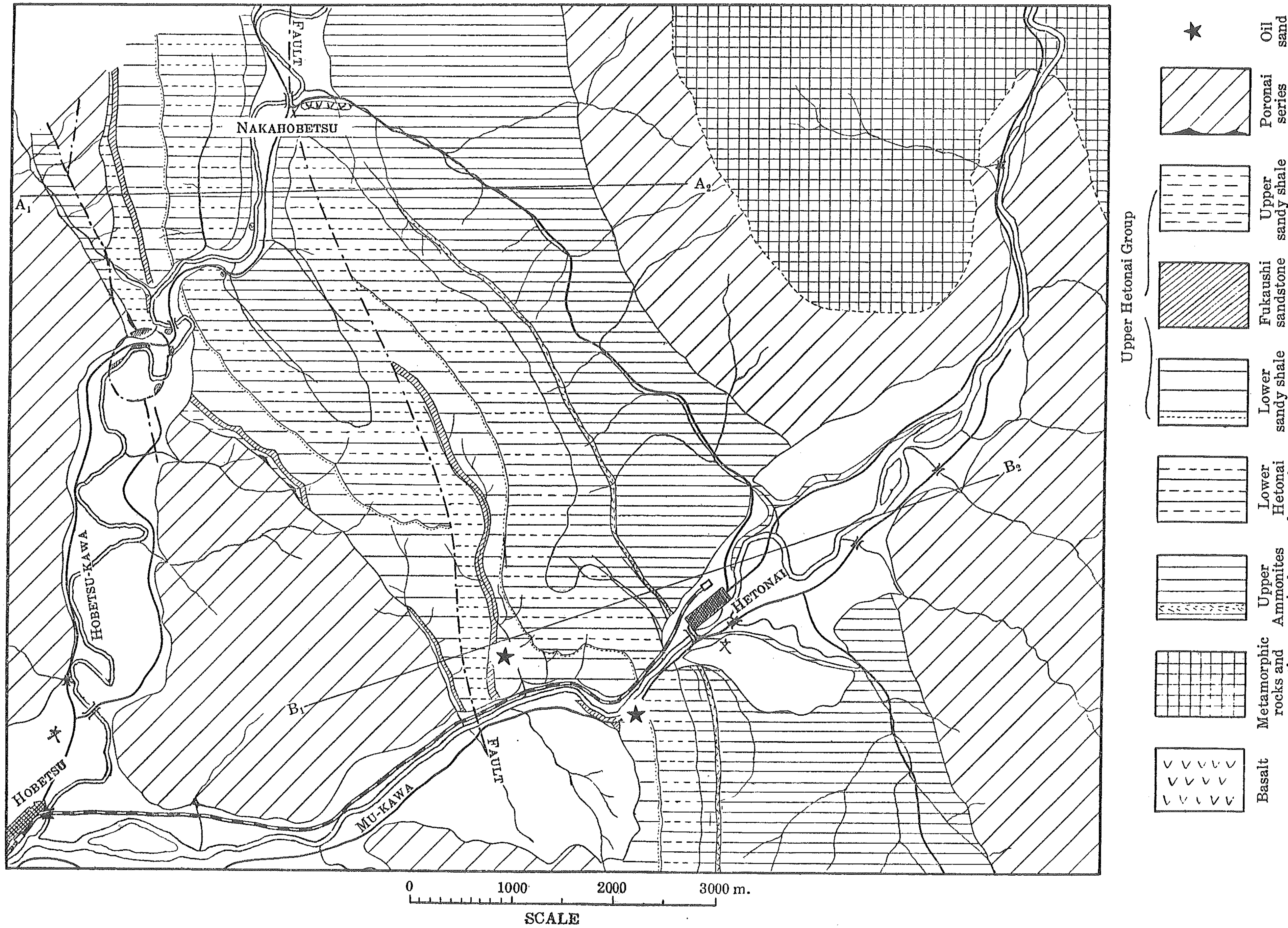

Figure 1. Geological Map of the Hetonai District.

LITHOLOGY

Of those Cretaceous sediments developed through Hokkaido, the Upper Ammonite bed is generally characterized petrographically by an argillaceous massive black shale. This shale predominates in the upper portion, while the rock of the lower portion of the bed is light gray in colour. The texture is uniform but looks rather like sandy shale.

Under the microscope, the rock is not uniform in texture, showing irregular lenticular aggregates of fine clay material in the thin section perpendicular to the bedding plane. Of those terrigenous matters transported from the land, minute fragments of black carbonaceous matter with irregular but usually elongated shapes are abundantly observed in black colour, from which the black colour of the rock may be derived. They are mostly coaly fragments, some of which are of free carbon.

Quartz has been also abundantly observed in the shale. The particles are usually angular. The size varies from 0.01 millimeter to 0.05 millimeter, and the average is about 0.02 millimeter in diameter. These angular fine grains of quartz may be due to the presence of volcanic ash.

Felspars are also found as in the similar occurrence of quartz. The particles are also mostly angular and the size varies as in quartz. Orthoclase is often kaolinized by weathering, although plagioclase in fresh aspect shows polysynthetic twinning. Some felspars are altered to other mineral with brilliant interference colour which is probably sericite. The grains of plagioclase are usually so small that the optical character is hardly determinable under the microscope.

Biotite is also very often found mostly in dark green coloured cleavage flakes with irregular but elongated forms, sometimes with folded structure. It never has been worn. Small scaly fragments are usually abundant. Double refraction is rather strong. There are pleochroic halos.

A very few grains of glauconite are also noted in the thin section. In some sections, a pale greenish tinge may be observed in the cementing materials, which probably represents finely disseminated chlorite. Green mineral which may be glauconite shows low index of refraction. Usually the particles are rounded in form. Some green minerals are usually observed in angular and flaky forms. They may be chlorite mineral altered from other minerals.

The cement that holds the shale grains and the filling materials together consists mainly of fine minute grains of quartz, felspars, and other minerals. Clay material which has usually altered to kaolin by weathering is also abundantly observed as an argillaceous matrix filling up the pores between the grains.

Considering the mineralogical constituents of the shale of the Upper Ammonite bed, the substance that comprises the rock is partly transported from the land, but is partly composed of pyroclastic material which is derived from the volcanic products during the period of the sedimentation of the Upper Ammonite bed.

EVIDENCE OF AGE

The Upper Ammonite bed in the present localities has yielded faunae that indicate Turonian and lower Senonian age, which may be correlated with other so-called Upper Ammonite beds in Hokkaido. The faunae collected in the present district are listed below:

Mesopachydiscus haradai (JIMBO)
Parapachydiscus sp.
Gaudryceras tenuiliratum YABE
Gaudryceras yokoyamai YABE
Gaudryceras striatum JIMBO
Gaudryceras denseplicatum JIMBO
Kotoceras damesi (JIMBO)
Kossmaticeras iburiense (YABE)
Pseudophyllites sp.
Phylloceras cfr. *ramosum* MEEK
Phylloceras ezoense YOK.
Tetragonites epigonus KOSSMAT
Tetragonites sp.
Puzosia japonica YABE
Puzosia planulatiforme JIMBO
Puzosia sp. α
Puzosia sp. (very large type) β
Hauericeras gardeni BAILY
Yezoites puerculus JIMBO var. *teshioensis* YABE
Bostrychoceras japonicum YABE
Hamites yabei NAGAO and SASA
Substriapticus yabei NAGAO

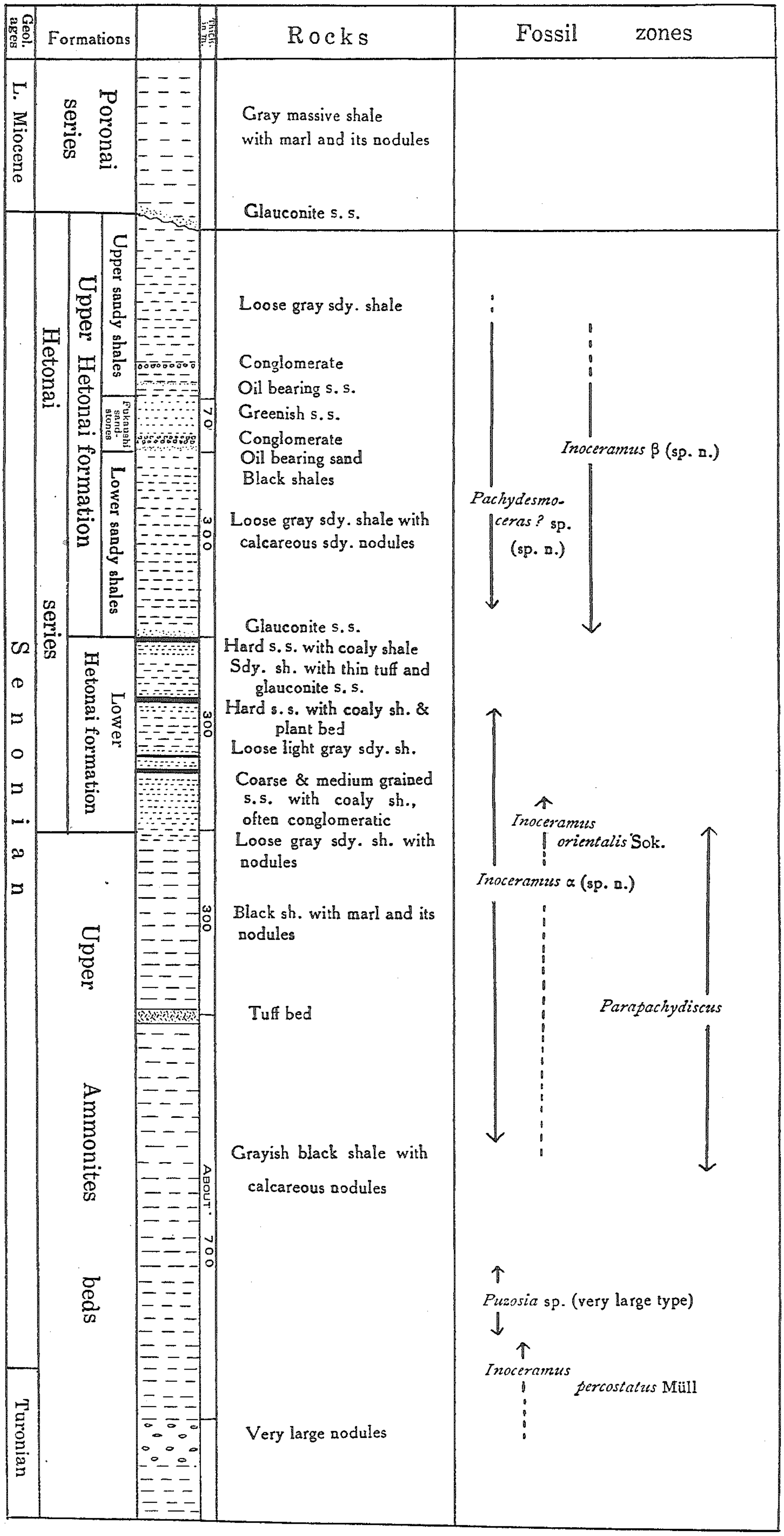

Figure 2. Geological Columnar Section of the Cretaceous Sediments of the Hetonai District.

Hamites (Polyptychoceras) sp. α
Baculites sp.
Inoceramus sp. (sp. n.) α
Inoceramus orientalis SOK.
Inoceramus ezoensis YOK.
Inoceramus cfr. *regularis* D'ORB.
Inoceramus percostatus MÜLLER
Inoceramus sp. (sp. n.?) α
Inoceramus sp. (sp. n.?) δ
Inoceramus vanuxemi MEEK and HAYDEN
Grammatodon sachalinensis SCHMIDT
Pecten cooperi WARING var. *radiate* YABE and NAGAO
Capulus casidalius YOK.

RELATION TO PETROLEUM

No oil is likely to be found in this bed in the present district, because it contains, so far as known, no petroliferous strata in which oil might have originated. Moreover, no formation occurs below it from which petroleum might have migrated. Therefore, the Upper Ammonite bed in this region can not be included among the rocks from which there is any possibility of obtaining indigenous oil.

HETONAI SERIES.

General Character

The Hetonai series is developed conformably above the Upper Ammonite bed, comprising two formations—the Lower and the Upper. The Lower Hetonai formation consists mainly of sandstone and frequently of conglomerate and shale of litoral or lucustorine deposits and partly fossiliferous sandstone, while the Upper Hetonai formation consists mainly of massive sandy shale and often of sandstone of marine deposit. The Upper Hetonai formation is oil-bearing, while the Lower Hetonai formation is mainly coal-bearing.

The Hetonai series is correlated with the Hakobuchi sandstone series developed in the coal fields of Hokkaida, in which thin lignitic coal seams occur and in which the characteristic Cretaceous floras are found.

Lower Hetonai Formation

General Features

The Lower Hetonai formation develops conformably above the Upper Ammonite bed, and is characterized by a massive hard sandstone which offers a very picturesque sight, as it piled high in a jagged ridge. But it frequently includes shaly rocks and conglomerate. Several poor coal seams are also found in this formation.

There are many kinds of sandstones which compose the Lower Hetonai formation, such as the compact sandstone with faint greenish gray colour, the green sandstone containing chlorite which gives the sandstone its light green colour, the light brownish gray sandstone with onion structure on weathering, and the gray compact medium sandstone characterized by a large amount of *Inoceramus* fossils. Of those many sandstones, the compact and faint greenish gray sandstone is the typical sandstone of the Lower Hetonai formation.

Lithology

The fresh hand specimens of the typical sandstone of the Lower Hetonai formation are compact in texture, and gray but faintly greenish in colour. It often contains small pebbles. On weathering it alters to gray in colour but still remains compact in texture. Macroscopically, the quartz and the felspars are visible in grains of about 0.2 millimeter to 0.7 millimeter in diameter, representing a medium coarse grained sandstone. Small fragments of volcanic rocks are also found in rounded shapes.

Under the microscope in thin section, the clastic nature of the rock is at once apparent. When first examining it, one's notice is attracted by the marked angularity of the grains that compose it. The half portion of them show angular boundaries; the other half of the grains show some evidence of rounding. Many of the grains have delicate points on their corners. The closeness of the spacing of the grains is notable. They fit very closely together with only a thin film of cement between them. Calcite is an important constituent of the cement. They are visible only under the microscope, but their presence is shown by an effervescence when the sandstone is treated with hydrochloric acid. Small flakes of a green mineral also occur in the cement. From their interference colours, pleochroism, colour and form, they are determined as chloride. The pale greenish colour of the cement is probably due to chloritic material. In some instances the grains fit very closely together without any cementing materials between them.

Quartz is the most important constituent of the rock. The grains of this mineral vary considerably both in size and in their degree of rounding, some of which show very angular and delicate points on their corners, as usually are shown in pyroclastic sediments. The grains, however, are about 0.1 millimeter to 0.6 millimeter in diameter. Secondary quartz is also abundantly found in the form of grains; it shows cryptocrystalline structure under the microscope. Secondary quartz grains are usually clouded by decomposition.

Felspar grains are also met with next in order. They are usually the same in size as quartz. Grains of orthoclase and plagioclase are numerous, but microcline is rarely observed in its characteristic lattice structure. The plagioclase felspars usually represent lamination twin, and are usually of the more acid varieties. The orthoclase felspars are usually clouded by decomposition products. The orthoclase sometimes shows the characteristic Carlsbad twinning. Some of the felspars of plagioclase and orthoclase are very fresh, as clear and limpid as the quartz, representing sharp angular boundaries, which may be the pyroclastic materials without any evidence of rounding.

Biotite is also found in cleavage flakes with jagged edges. Colour, clouded pale brown. Partial alteration to pale green chloritic matter is also observed. Strong adsorption is likewise parallel to the cleavage cracks. Biotite is also occasionally found in folded structure between other minerals.

Zircon is extremely rare. It occurs in small columnar crystals with rounded terminations, representing 0.3 millimeter across.

Besides the grains of single minerals, small fragments of effusive rocks are present, being about 0.2 millimeter to 0.6 millimeter across. Rounded and subangular blocks of effusives, consisting of lath shaped minute crystals of plagioclases are found. The minute crystals of plagioclases with 0.02 millimeter to 0.1 millimeter length represent microscopic flow structure. Minute plagioclases are too small to determine accurately their optical properties, but it may be said roughly that they are generally mediocalcic plagioclases such as andesine and labradorite which are usually found in mediobasis effusive rocks such as andesite and its varieties.

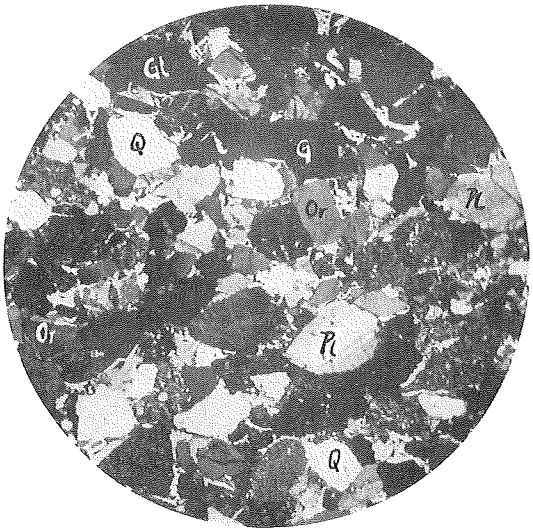

Figure 3. Typical sandstone of the Lower Hetonai Group (+Nicol. ×60).
Q, Quartz. Or, Orthoclase. Pl, Plagioclase.
Gl, Glauconite. G, Glassy quartz.

EVIDENCE OF AGE

The bed here designated Lower Hetonai formation lies conformably above the Upper Ammonite bed (Turonian and lower Senonian) described in the previous pages. The age of the formation may be defined as upper Senonian from its stratigraphic relation to the Upper Ammonite bed and also from fossils obtained from it listed as follows, and it is possibly correlated with the *Baculites saghalinensis* Zone (upper Senonian) in Saghalin described by S. SHIMIZU(1).

Inoceramus sp. (sp. n.) α
Inoceramus orientalis SOK.
Inoceramus vanuxemi MEEK and HAYDEN
Perna sp.
Ostrea sp.
Modiola sp.

(1) S. SHIMIZU: Cretaceous Deposits of North and South Saghalin. Annual Report of the Work of Saito-Ho-on Kai, No. 5, Sendai, Japan, 1929.

Spisula sp.
Callista sp.
Nilssonia serotina HEER
Asplenium dicksonianum HEER
Protophyllum (?) sp.

RELATION TO PETROLEUM AND COAL

Oil sand in this formation is exposed in Makaushi-sawa, Naka-hobetsu, which occurs as massive sandstone, but it gives evidence that it neither contains nor has generated oil in commercial quantity. This oil may have come from organic shales within the formation and is only of interest geologically in considering the genesis of oil in the Cretaceous sediments in Hokkaido.

Four coal seams occur in the Lower Hetonai formation, as are shown in the geological columnar section (Figure 2), but they are also not commercially productive, because rich in mineral matters like coaly shale representing about seven feet in thickness.

Upper Hetonai Formation

GENERAL FEATURE

The Upper Hetonai formation is the upper part of the Hetonai series classified stratigraphically into two horizons, either of which relates conformably to the other. The upper formation consists largely of marine shales and sandstones including a large amount of faunae, while the lower formation consists mainly of lucustrine or littoral sediments already described in the above pages.

The Upper Hetonai formation comprises lithologically five zones —the glauconite sandstone, the lower sandy shale, the oil sandstone, the Fukaushi sandstone, and the upper sandy shale. The lower sandy shale and the upper sandy shale are locally petroliferous including oil sands. The real thickness of the Upper Hetonai formation is more or less doubtful, because it is covered unconformably by the Poronai formation (lower Miocene) and locally is cut by the overthrusting fault between them. But its thickness is roughly about 670 meters in the present field.

Lithology

Glauconite Sandstone

The glauconite sandstone is the lowest part of the Upper Hetonai formation, consisting mainly of dark green massive sandstone about four meters in thickness.

The fresh hand specimen of the glauconite sandstone is dark greenish gray in colour. White felspar grains disseminated through the rock are easily recognized. At Naka-hobetsu it contains a large quantity of iron pyrite of cubic crystal about two or three millimeters in diameter. In general, the glauconite sandstone at Hetonai is medium coarse grained and uniform compact in texture. It alters into blackish gray colour under the action of weathering decomposition and usually is covered with grayish decomposed mantle. Occasionally the glauconite sandstone contains pieces of coaly fragments.

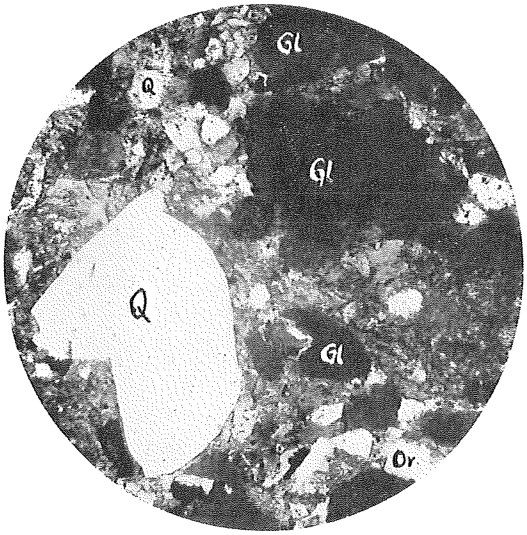

Figure 4. Glauconite Sandstone (×65).
Q, Quartz. Or, Orthoclase. Gl, Glauconite.

Under the microscope, the grains of the constituent minerals of the rock are not unique in size. The diameters of the grains range from a quarter to three quarters of a millimeter. When first examining it, in thin section, one is surprised at the marked angularity of the grains which compose it. Very few of the quartz grains and a majority of the glauconite grains show any evidence of rounding. Wedge-shaped pieces are common. It is evident that there was no great amount of abrasive action in the transportation of the grains of this glauconite rock to their places of deposition. Of the many kinds of mineral components of glauconite sandstone, glauconite is the most important constituent, with the grains of quartz and felspars next in order. Secondary calcite altered from ortholase is recognized. Carbonaceous black substances, the grains of magnetite and very rarely of olivine are also recognized.

Glauconite is the most important constituent of the rock, on which the dark greenish gray colour depends. In general the grains of glauconite are rounded or subangular. Their diameter ranges from 0.1 to three quarters of a millimeter; in colour, dark green. Occasionally there are small pockets or lenticular aggregates of the grains of glauconite in which the grains are densed. The glauconite may occur in so great abundance that it may be regarded as an essential part of the glauconite rock.

Quartz is quantitatively next in order of the constituents of the rock. The marked angularity of the quartz grains is recognized under the microscope. Very few of the grains, especially the larger ones, show any evidence of rounding. Small grains of quartz are commonly wedge-shaped in form.

Orthoclase and plagioclase are also numerous next to the grains of quartz, but microcline is rarely present. As a rule, the felspars are fresh and as clear and limpid as the quartz in the unaltered specimens of the sandstone. But the larger grains of orthoclase are clouded and sometimes altered into sericite and chlorite by decomposition.

Of those grains of minerals recognized in cement, enumeration may be made of quartz, felspars, calcite, chlorite, ferruginous oxide minerals, and organic carbonaceous substances.

Finally, taking into consideration the composition of minerals found in the glauconite sandstone, it may be said that the possible sources of their derivation are partly acidic igneous and sedimentary rocks, and are partly acidic pyroclastic materials which had been produced by the volcanic eruption at the end of the Cretaceous period.

Lower Sandy Shale

The lower sandy shale is also a member of the Upper Hetonai formation lying conformably above the glauconite sandstone bed. The upper part of the bed is petroliferous. The rock occurs usually in masses, but occasionally it interbeds with sandstone and also includes sandstone nodules within which bearing fossils of marine faunae and small fragments of plant. The rock is soft. The thickness is about 300 meters. The colour of the rock is usually gray, but when wet, it get more dark in colour. The decomposed hand specimens are usually grayish brown in colour. One can easily observe the rounded grains of quartz with a high powered handglass.

Under the microscope, the clastic nature of the rock is at once apparent. When first examining it, in thin section, one is surprised at the marked angularity of the grains that compose it. Very few of them show any evidence of rounding; the greater proportion of them show sharp angular boundaries. Wedge-shaped pieces are common and occasionally there are thin splinters with fine points.

Carbonaceous fragments of plant tissues are abundantly observed in black colour, which are the main ingredients of substances causing the gray colour of the rock. They are observed in uniform distribution through the rock. The fragments are very irregular in forms; some are fibrous and angular in shape. Some of them show a structure of plant tissue. They are usually black in colour but occasionally present a dark brown colour. The dimension of the fragments is widely variable ranging from about 0.05 millimeter to about 0.6 millimeter in diameter.

Quartz is the most important constituent of the rock. Most of the quartz grains show sharp angular boundaries. Wedge-shaped pieces are common. A few of the grains show some evidence of rounding. Generally, the angular grains of quartz represent fresh clear appearance in thin section, while the round grains show slightly clouded aspect. The dimensions of the grains are generally uniform, from 0.02 millimeter to about 0.07 millimeter in diameter. Flakes of glassy matter are also found, cloudy brown in colour with sharp angular boundaries, and dark between crossed nicols. They represent some inclusions such as fine minute mineral crystals and gas bubbles. Some of the glassy matters show vitritic structure with delicate points on their corners.

Next in order are grains of felspar. Grains of orthoclase and plagioclase are numerous, but microcline is rarely present. The plagioclase felspars are usually of the more acid varieties. As a rule the felspars are very fresh; in unaltered specimens of the sandy shale, the felspar is as clear and limpid as the quartz.

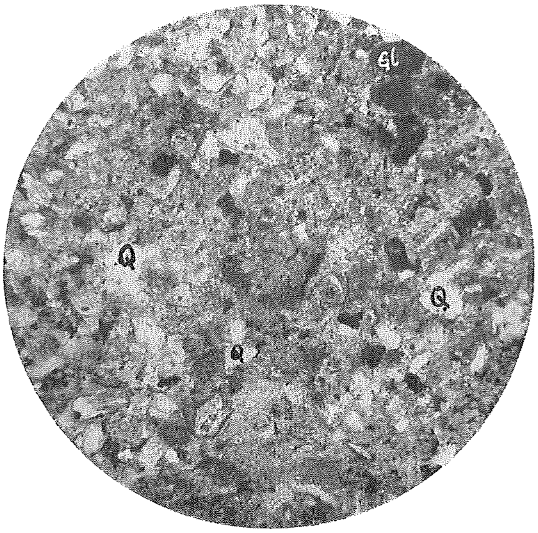

Figure 5. Lower Sandy Shale (×60).
Q, Quartz. Gl, Glauconite.

Chlorite pale green in colour is also fairly common in the sandy shale. It occurs in the form of large grains and flakes which seem to be original constituents of the rock. Minute scales, probably often secondary, are found in the cement. A pale greenish tinge may be observed in the cementing material, which probably represents finely disseminated chlorite. Some pale green cleavage flakes of biotite which have partly altered to chlorite are often observed. They still possess distinctly pleochroic halos. Between crossed nicols they show still partly high birefringence.

Biotite is also found in cleavage flakes of dull green colour usually about 0.01 to 0.08 millimeter across. Cleavage perfect. Flakes are not worn with jagged edges. Mostly they are folded between other minerals. Pleochroic halos are distinctly noticed; the direction of the greater adsorption is parallel to the cleavage cracks. Between crossed nicols it shows still high birefringence although frequently it is partially altered to chloritic matter in pale green colour.

Glauconite is also usually found in rounded or irregular grains or aggregates; they are rarely greater than 0.2 millimeter in diameter. Colour is various shades of olive green, dark greenish brown when altered. The great majority of the grains of glauconite are characterized by a cryptocrystalline structure. Birefringence variable, but aggregates usually show low polarization tints. Pleochroism is not observed.

Rutile. Free crystal grains are rarely seen to consists of the simple tetragonal prism (110), often capped by a pyramid (111). The commonest occurrence, however, is in the form of rounded prisms with indistinct terminations, and grains, of about 0.5 millimeter diameter. The colour is slightly pink red. Pleochroic halos are usually week. Maximum adsorption direction parallel to principal axes. It shows high birefringence with straight extinction.

Zircon is one of the heavy minerals of the rock, and occurs in colourless highly refracting prismatic grains. Occasionally pale brown stumpy crystals also occur. The crystal grains attain a length of about 0.4 millimeter. Birefringence high. Straight extinction. Pleochroic in coloured varieties.

Finally, the result of the petrographical study of the lower sandy shale under the microscope suggests that the rock is a mixture sediment of transported material from the land and pyroclastic material which was produced by the volcanic eruption at the close of the Cretaceous period.

Oil Sandstone

The oil sandstone is developed in the upper part of the lower sandy shale. The rock occurs in non-stratified masses. In general, the sandstone is coarse grained. The diameter of the grain is about one millimeter. The fresh hand specimen of the rock is grayish white in colour, but often is stained reddish brown by ferric oxide, and locally it is also stained black by some asphaltic substance with petroliferous oder. Megascopcically, quartz is the most important constituent represented in the composition of the rock. Felspars are next in order. Small organic fragments of carbonaceous substances are also seen.

Under the microscope the component minerals of the rock are rather rounded in form, and uniform in size, showing about 0.45 millimeter average diameter of the grains. The component minerals are mainly quartz, felspars, biotite, titanite, and organic carbonaceous fragments. The mineral grains are closely packed together and the cementing substance of ferruginous matter plays an important rôle.

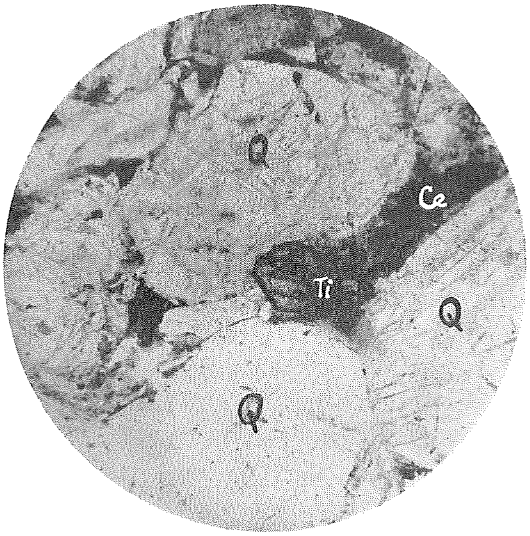

Figure 6. Oil Sandstone (×63).
Q, Quartz. Ti, Titanite. Ce, Cementing matters of felluginous and bituminous substances.

Of those quartz grains in the rock, some are subangular and others rounded in form, and measurements of their diameters are rather irregular varying from 0.1 to 0.8 millimeter. It is a noticeable fact that the most of the quartz grains in the rock have cracks running irregularly in many directions. This is one of the striking characters of the quartz grains of the sedimentary rocks.

Felspars are also observed in various types. They are subangular in form like quartz, and generally the grains have diameters of about 0.1 to 0.8 millimeter. Some of the orthoclases are altered into kaolin, but others are transparent and show Carlsbad twinning between crossed nicols. Plagioclase particles, like some of the orthoclases, are transparent and show laminated repeated twins like those of albite. Some of the felspars are transparent and show distinct cleavage lines parallel to the elongated axis, and also represent the optical angle which is about zero degree like that of sanidine.

Biotite is also rarely observed in angular cleavage flakes. They are all distorted and bent between other nonelastic minerals like quartz and felspars. In pleochroic halos the direction of the stronger adsorption is parallel to the cleavage cracks.

Titanite. Only one grain of this mineral has been met with as a very pale bluish white rounded short prismatic form. It shows two poorly defined equal cleavage cracks perpendicular to each other. The index of refraction is so high that it looks like a floating grain on other minerals. Double refraction is also much stronger than other minerals in the rock.

Grains of basaltic rocks are often observed under the microscope. Macroscopically, these grains look like scattered black rounded spots of 0.4 to one millimeter in diameter. Under the microscope, these rounded grains are the basaltic rock consisting of the interesting plagioclase of lath shape showing basaltic texture. Magnetite grains and augite altered to chlorite are also to be seen.

Generally, the closeness of the spacing of the grains is remarkable, but frequently the iron oxides and bituminous substances play a more important rôle as the cementing material.

Fukaushi Sandstone

The sandstone occurs conformably above the oil sandstone in the Fukaushi (深牛) valley. The thickness of the rock is from about fifteen meters to twenty meters. The rock occurs in masses with hard and compact texture to form ridges of the hills, and also to form gorges in the valley.

When fresh, the typical Fukaushi sandstone is dark greenish gray in colour. The texture is dense and the grains are closely packed. In general, the sandstone is medium grained. At first glance the sandstone just resembles the *Trigonia*-sandstone of the Upper Cretaceous sediments in the Ishikari coal fields of Hokkaido.

Under the microscope in thin section, at first glance, one is surprised at the marked angularity of the grains that compose it. Although some grains show some evidence of rounding, some other part of them show sharp angular boundaries. Wedge-shaped pieces are common and often there are thin splinters with fine points. It is evidence that there was no great amount of abrasive action during the transportation and sedimentation of the grains of this rock. The diameter of the grains ranges from 0.15 millimeter to 0.5 millimeter. The closeness of the spacing of the grains is remarkable. They fit very closely together with calcareous cement between them.

Small flakes and film of a green mineral occur also as the cement and matrix. From their interference colour, pleochroism, and colour, they are determined as chlorite. Of those many kinds of minerals that compose the sandstone, quartz is the most important mineral constituent of the rock. Felspars are next in order in quantity.

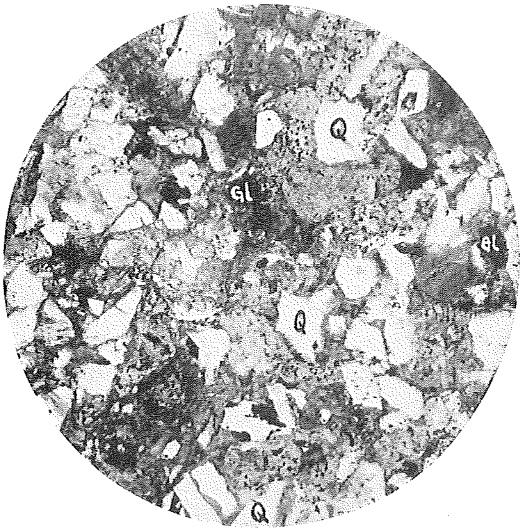

Figure 7. Fukaushi Sandstone (×60).
Q, Quartz. Gl, Glauconite.

Quartz occurs as an essential part of the sandstone with grains partly rounded, but partly very angular without any evidence of abrasive action. Secondary growth of silica on the grains is met with in cryptocrystallizing aggregates. Glassy matter is also found with sharp angular boundaries. Usually they represent a cloudy appearance from decomposition. But they are still partly dark between crossed nicols.

Grains of orthoclase and plagioclase are also numerous. The plagioclase felspars are often of the laminated microcline crystal with lattice structure. As a rule the felspar particles are fresh and as clear and limpid as the quartz. In some instances they are clouded by decomposition. The grains of felspar are also remarkably angular in form without any evidence of abrasive action.

Chlorite grains, besides the cementing chlorite, occur also numerously as secondary mineral altered from the mafic minerals and felspars. They are also pale or dark green in colour with pleochroism and peculiar interference colour.

Biotite also is often seen in cleavage flakes, although it is partly altered to chlorite on decomposition. Where the mineral has escaped decomposition, it is of dark brown colour with intense pleochroic halos. The elongated flakes are bent between other minerals.

Besides these grains of single minerals, small fragments of effusive rocks are abundantly found. They are irregular in form, but the greater proportion of them show an evidence of rounding. These fragments are all effusive rock like andesite showing the flow structure of small lath shaped crystals of felspars which are about 0.07 millimeter in length. The groundmass of these fragments of effusive rocks are altered to chlorite and serpentine from mafic minerals by decomposition.

Green hornblende is found in cleavage fragments with perfect cleavage, some of which show the characteristic cleavage angle of hornblende in cross section. It has altered partly to chlorite by weathering. But the mineral which has escaped decomposition shows dark green colour with strong pleochroic halos.

Of orthite (allanite) only one grain of the mineral of epidote group was found in the sandstone. It is about 0.25 millimeter in diameter. It has dark reddish brown colour and is intensely pleochroic with a high double refraction and high indices of refraction. It is also characteristically partly enveloped by colourless clinozoicite.

From the consideration of the above mentioned minerals, the sandstone is a mixture sediment of terrigenous material derived from acidic igneous and sedimentary rocks and the acidic pyroclastic materials which had been produced by volcanic eruption during the period of the sedimentation of the sandstone.

Upper Sandy Shale

The upper sandy shale is found at the top of the Cretaceous formation in the present district. The thickness of the bed is roughly about 160 meters but its exact measurement is doubtful, because it is cut by erosion and covered unconformably by the Poronai shale (lower Miocene), and also locally it is thrust by faulting over the Poronai shale. The rock is of reddish brown colour at the surface outcrop. It shows uniform texture. But occasionally it contains sandstone nodules in which there are found the fragments of plants, *Inoceramus,* and Ammonite.

Under the microscope, the clastic nature of the rock is at once apparent. When first examining it in thin section, the greater proportion of the mineral grains show evidence of rounding, but some of them show sharp angular boundaries and delicate points on their corners. Wedge-shaped pieces are common and occasionally there are thin splinters with fine points. They are also pyroclastic materials. The closeness of the spacing of the grains is notable. They fit very closely together with only a thin film of cement between them, and the impregnating ferric oxide which gives the sandstone its reddish brown colour is found as cementing film.

Quartz is by far the most abundant mineral in the rock. The grains are mostly rounded, but sometimes very angular without any evidence of abrasive action. The angular quartz grains are as a rule fresh. The grains are usually from 0.05 millimeter to 0.2 millimeter in diameter. Secondary growth of silica on the grain is met with in cryptocrystalline aggregates.

Felspars probably rank next to quartz in abundance and dissemination through the rock. Plagioclase and orthoclase are usually of the more acidic varieties. As a rule, they are very fresh and clear like the quartz. It is a striking character that these fresh and clear feldspars are also very angular and have delicate points on their corners. In some instances there are found some felspars slightly clouded by decomposition.

Biotite, the black mica, is found in cleavage flakes, although it has altered partly to chlorite and limonite on weathering. Where the mineral has escaped decomposition, it is of a dark brown colour with intense pleochroic halos.

Muscovite is also rarely found in colourless cleavage flakes with high birefringence.

Limonite is found abundantly as a cementing material between the grains in the rock, and this impregating ferric oxide gives the rock its reddish brown colour. The granular limonite is probably derived from the ferrugenous mafic minerals such as biotite, pyroxene, and others.

Chlorite and serpentine are also usually found in small flakes of green minerals occurring in the cement. They show a pale or dark green colour with pleochroism and peculiar interference colours.

Some grains of chlorite which might have been derived from other minerals occasionally exhibit interference figures with noticeable pleochroism.

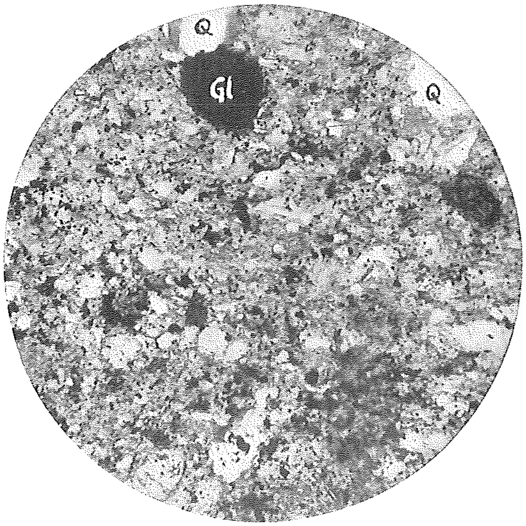

Figure 8. Poronai Shale (×63).
Q, Quartz. Gl, Glauconite.

Tourmaline is rarely found in radial aggregates of acicular crystals which probably are one variety of a blue colour with about 0.2 millimeter in diameter. It represents strong adsorption perpendicular to the principal zone.

Flakes of glassy matter are also found cloudy yellowish in colour with sharp angular boundaries. Usually they represent a cloudy appearance with minute grains of secondary chlorites by decomposition. But they are still partly dark between crossed nicols. Some of the grains show a cryptocrystalline structure of secondary quartz between crossed nicols.

Glauconite occurs very rarely in the form of rounded grains of dark green colour; they are rarely greater than 0.15 millimeter in diameter. It is characterized by a cryptocrystalline structure with very faint pleochroism.

It is one of the striking features of the sandy shale that a number of small fragments of volcanic rocks are recognized under the microscope. Most of the grains show an evidence of rounding; a small proportion of them show angular boundaries. The grains are about 0.1 millimeter to 0.3 millimeter across. They show microscopical fluidal texture with minute lath shaped crystals of plagioclases of about 0.05 millimeter in length. The groundmass of the rock is of isotropic glassy matter, but partly it shows chloritic green substances with other fine minute crystals of mafic minerals. The small lath shaped plagioclase is so minute that its optical property is not exactly determined but it may be mediocalcic plagioclase such as andesine or labradorite by its refractive indices.

From the evidence presented, it may also be said that the upper sandy shale is partly derived from the acidic igneous and sedimentary rocks, and partly from the acidic pyroclastic materials which had erupted during the period of the sedimentation of the rock.

EVIDENCE OF AGE

Fossils are not very abundant in the Upper Hetonai series. But it is a characteristic feature that many of these faunae are largely different from those found in the Lower Hetonai series and the Upper Ammonite bed. The formation is possibly correlated with the *Phylloceras nera* FORBES-Zone (upper Senonian) in Saghalin described by S. SHIMIZU(1).

The stratigraphic position of the Upper Hetonai series indicates that it is of the upper Senonian age, because it lies conformably above the Lower Hetonai series which is also considered to be upper Senonian in age. Palaeontological evidence shows that the Upper Hetonai series belongs to the upper Senonian epoch.

The species obtained from the Upper Hetonai series in the present district are listed as follows:

Kotoceras damesi (JIMBO)
Phylloceras cfr. *surya* FORBES
Phylloceras (?) sp. (sp. n.)
Phylloceras (?) sp. (sp. n.)
Tetragonite sp. (sp. n.)
Puzosia sp. γ
Pachydesmoceras (?) sp. (sp. n.)
Hamites sp. β
Inoceramus sp. (sp. n.) β
Inoceramus aff. *crippsi* MANT.

(1) S. SHIMIZU: Cretaceous Deposits of North and South Saghalin. Annual Report of the Work of Saito-Ho-on Kai, No. 5, Sendai, Japan, 1929.

Acila sp. α
Acila sp. β
Gervilleia (?) sp.
Lucina sp.
Callista sp.
Thrasia sp.
Solemya cfr. *subplicatus* MEEK and HAYDEN
Trigonia subovalis JIMBO
Trigonia subovalis JIMBO var. *minor* YABE and NAGAO
Helcion (?) sp.
Anisomyon cfr. *sexsuicatus* MEEK and HAYDEN
Solarium sp.
Callianassa sp.

RELATION TO PETROLEUM

The oil sandstone of the Upper Hetonai series is exposed at the railway cutting near the town of Hetonai representing steep over-thrust monoclinal structure. Here the sandstone contains no oil in commercial quantity, but it is only geologically an interesting oil showing in the Cretaceous sediment in Hokkaido. Petroleum might have originated in the lower sandy shale of the Upper Hetonai series itself and migrated into the sandstone in the upper part of the series above.

TERTIARY SYSTEM

Poronai Series

GENERAL FEATURES

The Poronai series is the only Tertiary sediment exposed in this area, by which the Cretaceous sediments are overlapped unconform-ably on both the eastern and western sides of the district. Marked structural breaks are locally shown; evidence of difference in dip and strike appears. Furthermore, there is a marked change in lithology at the contact with the Hetonai series. This Poronai series may be traced westward to the type locality of the Poronai series in the Ishikari coal field, where a much more complete faunae and the typical black massive shale of the Poronai age are known to occur. The Poronai series in the present district is also composed of mas-sive gray or black shale, often interbedding with white tufaceous sandstone a few tenth of meters in thickness in the middle part of the series. This white tufaceous sandstone occurs in the upper part of the Poronai shale in the Ishikari coal field. The Poronai shale is soft, so that it is subjected to erosion and is easily sculptured into broad valleys and low hills. The upper part of the series is of the massive sandy shale, while the lower part is of the argillaceous clay or massive shale. At the base of the Poronai shale, there occurs characteristically the glauconite sandstone two or three meters thick throughout all the Ishikari coal fields. Calcareous nodules often enclosing marine faunae are found in the shale.

The Poronai shale is usually cut off by overthrusting faults at the boundaries between the shale and the Upper Hetonai series, which is running NW-SE. Therefore, it is hard work to determine its thickness, but it may be more than 3000 meters.

EVIDENCE OF AGE

It is a rather difficult task to determine definitely the age of the Poronai shale in the present district, because paleontological collections are more or less incomplete. But it may rather safely be considered to belong to the lower Miocene period judging from its stratigraphical position with relation to other formations whose ages are known. The species listed below are collected from this series in the district:

Yoldia lischkei SM.
Yoldia sp.
Acila mirabilis AD.
Tellina altinata SAY var. chibana YOK. (?)
Macoma dissimilis MART.
Macoma sp.
Thracia sp.
Cardium pauperculus YOK.
Cardium shinjiense YOK.
Venericardia ferruginia (YOK.)
Venericardia sp.
Macrocallista chinensis CHEM.
Thyasira nipponica YABE and NOMURA
Ostrea sp.
Natica janthostoma DESH.
Voluta megaspira SOW.

Chrysodoms despectus L. (?)
Turritella sp.
Dentalium sp.
Hexacoralla
Callianassa muratai NAGAO
Cyclamina compressa CUSHMAN

RELATION TO PETROLEUM

Generally, the Poronai shale is a source of oil. The shale in the Ishikari coal fields northwest of the present field is also massive black shale in which oil might have originated and local oil seepages are known. Oil seeps found in the shale usually come from the fracture or fault fissure openings and are not found in the porous sandstone. In the present district the Poronai series is also composed of massive black marine shale, but no oil seepage is found, although in the neighbourhood west of the present field, a marked oil seepage was found for which some testing wells were once drilled.

IGNEOUS ROCKS

BASALT

The effusive rock occurs as an intrusive sheet of basalt near the top of the Upper Ammonite bed in the region of Naka-ho-betsu (中穂別)。The rock is very dark gray in colour and compact in texture. Porphyritic plagioclase and monoclinic pyroxene are often megascopically recognizable.

Under the microscope phenocrysts are not seen very abundantly in thin section. The groundmass is holocrystalline and basaltic in texture, consisting of plagioclase, quartz, calcite, magnetite, and chloritic substances. Through the secondary alteration many constituent minerals of primary origin, such as plagioclase, pyroxene, and other minerals are seen to be changed into secondary products.

The porphyritic plagioclase has marked zonal strucure and shows euhedral form with albite-twinning, being 1 millimeter to 1.5 millimeter in length. It is determined as labradorite by the maximum symmetry extinction angle. The alteration of inner cores into nearly opaque substances is usually found.

The pyroxene sparingly occurs in subhedral to euhedral forms, showing oblique extinction.

The quartz is often found in the interstices of other minerals and has many inclusions of undetermined acicular minerals, but in regard to the origin of this quartz, it is doubtful wheher it is primary or secondary. Between the grains of plagioclase and quartz, the chloritic substances and calcite probably derived from the original mafic minerals in the groundmass are scattered.

STRUCTURE

The structure of the region mapped on figure 1 is typical of the south eastern coal field of Hokkaido, which is comprised of folds and faults, in places tightly compressed and complicated by overturned folding. In general, the direction of the structural axes of the region is nearly NW-SE, and this trend is reflected in the topography. Two main periods of general deformation are indicated by a study of the structure of the coal fields—one at the end of the upper Cretaceous period after the deposition of the Upper Hetonai formation and the other at the end of the upper Pliocene period.

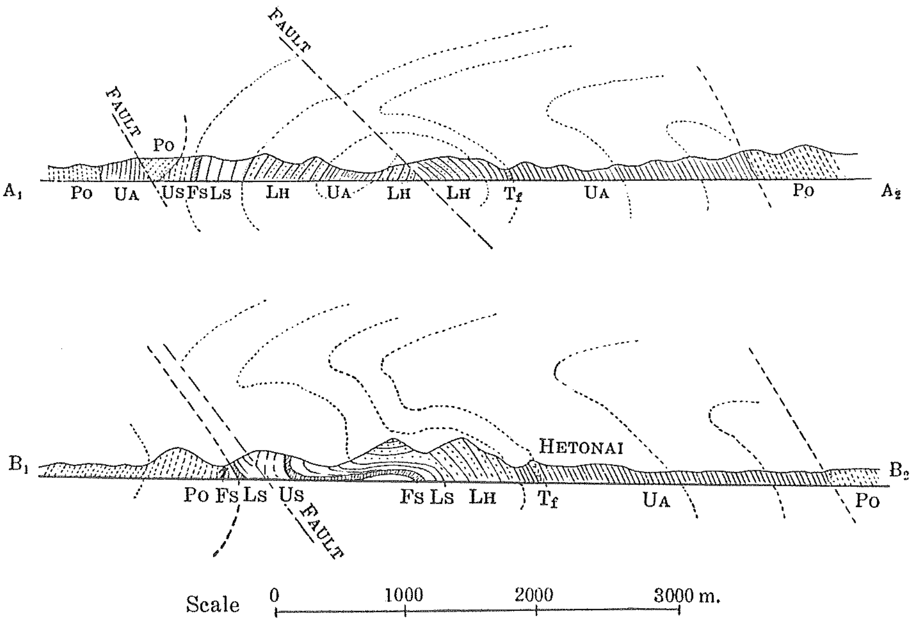

Figure 9. Po=Poronai Series, Us=Upper Sandy Shale, Fs=Fukaushi Sandstones, Ls=Lower Sandy Shales, LH=Lower Hetonai Group, Tf=Tuff Bed, UA=Upper Ammonites Beds.

The folding and faulting did not take place all at once in either period. Some of the strata were folded more than others and younger deposits were laid down upon the faulted and eroded edges of the older beds. It is largely on this evidence that the different formations have been separated. No one could say that these deformative movements are not even now in progress, because of the earthquakes that occur now and then in the region of south eastern Hokkaido.

The structure evidence of the steep reversed monoclines along the NW-SE direction and the closely compressed and locally overturned folds indicate that the deformation resulted from such compressive stresses exerted in a NE-SW direction. Every one can easily observe the split fissures of the deformed Fukaushi sandstone and the Lower Hetonai sandstone by strong lateral pressure as is shown in Figure 9.

PETROLEUM

The surface evidence of oil is closely associated with the formations in which oil originates—that is, the Upper Hetonai formation (upper Cretaceous) and the Poronai formation (lower Miocene). The most important oil sand occurs in the middle part of the Upper Hetonai formation. Oil seepages and outcropping oil sands are important criteria in determining the favorableness or unfavorableness of any locality for oil. Although surface indications of this type do not prove that paying quantities of oil may be obtained by drilling, they do show that oil is present in certain strata of the region. Even though the organic shales from which the oil is derived are present and the structure is conductive to the accumulation of petroleum, the chances of striking oil are much greater if surface indications can be found at some place where the supposed oil bearing formation crops out.

But in the present region, the surface indication of oil in the Cretaceous sediments is not so significant economically, because the structure is so very complicately disturbed as not to be conductive to the accumulation of petroleum and also the shales from which the oil is derived are not very bituminous although the sands into which oil has migrated are present. Therefore, the present region is geologically only an interesting locality to show the oil indication in the Cretaceous sediments in Hokkaido.

SUMMARY

In the Hetonai district there develop the Upper Cretaceous sediments (Hetonai series) which could be identified with the Hakobuchi sandstone (upper Senonian) in the Ishikari coal fields, Hokkaido, comprising two formations—the Lower and the Upper. Comparing with the Cretaceous sediments in Saghalin, the Upper Hetonai formation coincides with the Zone of *Phylloceras nera* FORBES, while the Lower Hetonai formation coincides with the Zone of *Baculites saghalinensis* SHIMIZU.

Although the Cretaceous oil is thus scantily found in Hokkaido, it does not play any important rôle in economics of petroleum at the present time. But this is one of the interesting problems connected with the geological distribution of oil in the oil regions of the western Pacific Coasts where the most productive geological horizon of oil is usually of Tertiary sediments.

In the present district the Cretaceous oil indications are usually found in the Upper Hetonai series of the marine sediments of the Upper Cretaceous age (upper Senonian). The Tertiary oil is also found in the Poronai shale (lower Miocene), but, it also is not productive.

The lithological properties of the Cretaceous sediments in the present region show also some characteristics of the terrigenous sediments; the sediments of the Cretaceous and the Tertiary ages in the present region are partly derived from the acidic igneous and sedimentary rocks and partly from the acidic pyroclastic materials which had erupted during the sedimentation of the rocks.