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## TERTIARY OROGENY IN HOKKAIDÔ.

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The Island of Hokkaidô (Fig. 1), one of the four main islands of Japan, is geologically divisible into two distinct parts, western Hokkaidô and the main part of the island. These two parts are separated from one another by a broad depression of post-Tertiary

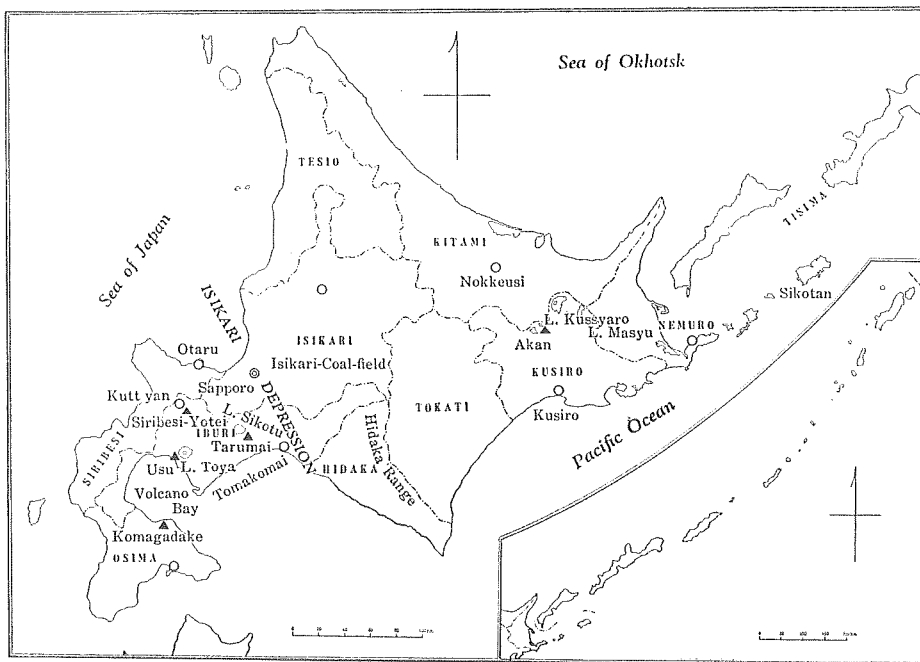


Fig. 1.

date, the Sapporo-Tomakomai or Isikari Depression. Western Hokkaidô<sup>(1)</sup> is characterized by the absence of Mesozoic and Palaeogene formations and represents a direct continuation of northern Honsyû to the south. The main portion of the island may be subdivided into

(1) T. NAGAO and Y. SASA: On the Deposits and Geological History of the Cenozoic Age in Western Hokkaidô (in Japanese). Journ. Geol. Soc., Japan, Vols. 41 and 42, 1934-35.

two rather indistinct parts, central and eastern Hokkaidô. Central Hokkaidô is the southern elongation of Saghalien; the geological formations and structures are quite similar to those of the latter. The Hidaka range, the backbone of the island, forms the divide between central and eastern Hokkaidô running meridionally and including a number of high mountains, some peaks of which exceed 1400 meters in altitude. Eastward from the range there develop extensive low terrains to the coasts of Sea of Okhotsk and the Pacific; westward extend also low lands which are, however, interrupted by a narrow meridional Median Depression.

In central Hokkaidô, is found the most complete succession of rocks ranging from the Palaeozoic to the Recent, excepting the greater part of the Mesozoic. The Tertiary sediments, together with the older sedimentaries, are arranged parallel to one another with a general N-S trend and comprise the following subdivisions:

|                           |   |                                         |                                               |
|---------------------------|---|-----------------------------------------|-----------------------------------------------|
| Superjacent<br>complexes. | { | Alluvium.                               | Terrace and river deposits and volcanic ashes |
|                           |   | .....unconformity .....                 |                                               |
|                           | { | Diluvium.                               | Higher terrace deposits and volcanic detritus |
|                           |   | .....unconformity .....                 |                                               |
|                           |   |                                         | Nopporo bed, sand and gravel                  |
|                           |   |                                         | .....angular unconformity .....               |
|                           |   | Pleiocene.                              | Takikawa beds                                 |
|                           |   |                                         | .....distinct angular unconformity .....      |
|                           |   | Pleiocene.                              | Oiwake beds                                   |
|                           |   |                                         | .....conformity .....                         |
|                           |   | Miocene.                                | Kamogawa beds                                 |
|                           |   |                                         | .....partial unconformity .....               |
|                           |   | Miocene.                                | Kawabata series                               |
|                           |   |                                         | Kawabata beds                                 |
|                           |   |                                         | Takinoue beds                                 |
| Basement<br>complexes.    | { | Lower Miocene<br>or Upper<br>Oligocene. | .....partial distinct unconformity .....      |
|                           |   |                                         | Poronai series                                |
|                           |   | Palaeogene.                             | .....unconformity .....                       |
|                           |   |                                         | Isikari series                                |
|                           |   |                                         | Upper Isikari series                          |
|                           |   |                                         | Middle Isikari series                         |
|                           |   |                                         | Lower Isikari series                          |
|                           |   |                                         | .....unconformity .....                       |
|                           | { | Cretaceous.                             | Cretaceous formations                         |
|                           |   | .....unconformity .....                 |                                               |
|                           | { | Upper Jurassic ?                        | Onisasi series                                |
|                           |   | .....distinct unconformity ? .....      |                                               |
|                           |   | Palaeozoic.                             | Hidaka series                                 |
|                           |   |                                         | .....distinct unconformity ? .....            |
|                           |   | Palaeozoic.                             | Kamuikotan series                             |

Toward the end of the Cretaceous age, the whole region of Hokkaidô emerged and subsequently suffered profound subaerial denudation. Although the Palaeogene Lower Isikari series,<sup>(1)</sup> which is terrestrial in origin, covers the Cretaceous always with a distinct unconformity,<sup>(2)</sup> there is no evidence of marked disturbance having occurred between these two complexes. The first Eocene invasion of water in central Hokkaidô is indicated by the Middle Isikari which is rich in marine mollusca in its whole thickness. The period following was characterized by repeated small oscillations of water, the Upper Isikari consisting of coal-bearing terrestrial deposits and marine and brackish water sediments in alternation. The Palaeogene transgression never reached western Hokkaidô where a long land-condition continued throughout Mesozoic and Palaeogene times; the oldest deposits covering the Palaeozoic are Neogene rocks.

After the deposition of the Isikari, marine water regressed from central Hokkaidô and denudation followed. The Poronai period of a marine transgression on this land was opened with quiescence. This complex was not separated from the Isikari by any intense orogeny, the movement having been a wide and gentle upwarding of the region concerned. The relation of the Poronai to the Isikari, however, is always unconformable<sup>(3)</sup> within the Isikari (Ishikari) coal-field in central Hokkaidô. A similar condition prevails in other parts of the island. Moreover, at Hetonai<sup>(4)</sup> in Iburi, the Poronai overlies the inverted and folded Cretaceous rocks and in the southern part of Isikari, Mr. ÔTATUME (OHTATSUME) had observed that the Palaeogene formation had been folded and then eroded before the Poronai time.

The Kawabata-Oiwake period following the Poronai is marked by a new and continuous marine transgression in a complete cycle of

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(1) H. IMAI: Stratigraphical Studies of the Coal-bearing Tertiary of the Ishikari Coal-Field, the Ishikari Series (in Japanese). Journ. Geogr. Soc. Tôkyô, Vol. 36, 1924.

(2) H. IMAI: Stratigraphical Relation between the Coal-bearing Tertiary (the Ishikari Series) and the Cretaceous Deposits in the Ishikari Coal-Field (in Japanese). Journ. Geol. Soc. Tôkyô, Vol. 31, 1924.

(3) H. IMAI: On the Relation of the Poronai Bed to the Coal-bearing Formations in the Ishikari Coal-Field (in Japanese). Contribution from the Institute of Geology and Palaeontology, Tôhoku Imperial University, in Japanese Language, No. 1, 1921.

(4) K. UWATOKO and K. OHTATSUME: The Upper Cretaceous Oil-bearing Sedimentary Rocks of Hokkaidô. Journ. Fac. Sci., Hokkaidô Imp. Univ., Ser. IV, Vol. 2, 1933.

sedimentation, though presumably interrupted at places by local unconformities. The greater part of the island was submerged during the Oiwake time, with a few scattered islands above water. One of the most intense orogenic movements in Hokkaidô commenced after the deposition of the Poronai and continued toward the late Tertiary<sup>(1)</sup> age. The Kawabata associates, closely as a usual thing, with the Poronai in the Isikari coal-field, no distinct disturbance being marked between these two complexes, but at other places the Kawabata often overlies the Poronai with a distinct unconformity and, moreover, widely overlaps the ancient rocks throughout the island. Around the Kabato Palaeozoic mass to the north of the Isikari Depression, the Poronai is much folded, sometimes upturned, and overlaid by much less disturbed Kawabata and Oiwake series.

The continuation of this orogeny is indicated by the presence<sup>(2)</sup> of numerous large and small blocks of serpentine and the Kamuikotan Palaeozoic rocks especially in the lower part of the Kawabata series. Moreover, the complex is characterized by the predominance of conglomerate-layers and by the frequent occurrence of interrupted and disturbed sedimentation; crossbedding, submarine sliding, intraformational conglomerate, and abrupt thinning out of layers are rather common in the whole complex.

The very complicated structure of the Isikari coal-field<sup>(3)</sup> and the inversion of strata of the Cretaceous, Palaeogene and Poronai, imbricated structure, and several translated rootless rock sheets (Decke)<sup>(4)</sup> are due to a phase of this long-continued diastrophism. The most conspicuous example is in the vicinity of Momiziyama near the Yûbari coal-mines. Here a rootless mass of the Kamuikotan metamorphic rocks with associated serpentine rests upon a folded Kawabata. It is noteworthy that there is no exposure of these ancient rocks within 20 kilometers of this locality. The Poronai is involved in the imbrication and inversion, and hence this movement was of post-Poronai date, and the rootless mass of Momiziyama, being found

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(1) T. NAGAO, K. CTATUME and R. SAITÔ: The Geological Structure of Central Hokkaidô. (in Japanese). Journ. Geol. Soc. Japan, Vol. 40, 1933.

(2) T. NAGAO: "Nappes" and "Klippes" in Central Hokkaidô. Proc. Imp. Acad., Vol. 9, 1933.

(3) H. YABE: Geological Guide to the Excursion to the Ikushunbetsu Coal Mining District, Ishikari Coal Field, Hokkaidô. Third Pan-Pacific Congr., Tôkyô, Guide Book, 1926.

(4) T. NAGAO: "Nappes" and "Klippes". Op. cit.

upon the Kawabata, is attributed to a post-Kawabata event. Thus the continued crustal movement, which possibly consisted of the upheaval of an ancient massif and first building as well as the subsequent westward advance of some of the "nappes", described on another occasion, was accompanied by an intense denudation that went on side by side with the sinking of the epicontinental sea in the front where a thick accumulation of the sediments of the Kawabata and Oiwake beds took place.

Toward the late Tertiary, at the close of the Oiwake period, the last phase of these orogenic movements occurred and all the rocks from the Cretaceous to the Oiwake were disturbed, folded and faulted before the deposition of the Takikawa bed. As the result of this last movement, there appeared a rather narrow and meridionally elongated embayment, separating central Hokkaidô from western, nearly at the present site of the younger Isikari depression, and extended more southward and northward. In this shallow water was laid the Takikawa, ranging from Middle Pleiocene to Upper Pleiocene, which covers the tilted Oiwake and older rocks in a distinct angular unconformity.

The post-Oiwake movement was suffered by the strata in almost the whole area of the island. In the northernmost part of central Hokkaidô, around Nakatombetu in Kitami, the Kawabata and Oiwake were depressed into a narrow meridional trough in a syncline. This trough is filled by the Nakatombetu bed, littoral sediments with aggregations of shell fragments, which covers the depressed Tertiary in a clino-unconformity and indicates a marine invasion into this trough. The Nakatombetu is considered as nearly equivalent to the Takikawa or the Setana in western Hokkaidô to be described later. The Median depression referred to before, the northernmost part of which is represented by the trough of Nakatombetu, separates the Hidaka Palaeozoic rocks on the east from the Kamuikotan and Cretaceous formations on the west and runs southward, being traceable as far as the eastern part of Ishikari. It extends, though less indistinctly, further south near the southern end of central Hokkaidô. This depression is interrupted by young volcanics at places, but it is indicated by a few circular or elliptical physiographical basins, of which the Asahigawa basin is the most noted. The greater length of the depression is occupied by Pleistocene and Recent deposits. It is evident that the depression owes its origin to the pre-Takikawa or possibly to the post-Takikawa movements to be described below.

The result of the pre-Takikawa disturbance is also well observable in western Hokkaidô.<sup>(1)</sup> In this region the slightly tilted Setana series, equivalent deposits with the Takikawa, overlies the Neogene Tertiary which comprises three marine formations and corresponds as a whole to the Kawabata-Oiwake. These three formations, conformable to one another, were much folded and faulted before the opening of the Setana time. The orogenic movement, which occurred here, was succeeded by a long interval of denudation, followed by a general uplift. There are preserved numerous extensive summits now elevated in some cases to a height of more than several hundred meters above sea-level. The Setana itself, overlapping the older rocks, indicates ancient embayments of various forms embraced in the late Tertiary land of western Hokkaidô. In eastern Hokkaidô this movement seems to be masked by the post-Tertiary disturbance, but as there is no extensive development of the Takikawa, it is most probable that general uplift was associated with folding of strata; the structure now observable may have to some extent been constructed at this time.

Thus it is very probable that the pre-Takikawa diastrophism which began at the post-Poronai disturbance and continued and culminated toward the end of the Oiwake, through the Kawabata when the "nappes" advanced westward, was the latest and most violent orogeny to influence the whole area of Hokkaidô. The withdraw of water from the greater part of the island occurred in association with this movement at the end of the Oiwake period, and the present general outline of the island with the leading geological structure of a north-south trend was established. The Takikawa and Setana beds are very localized in distribution, being extensive only in the southern part of western Hokkaidô, and do not contribute much to the present outline of the island, only fringing the older land area which resulted from the major diastrophism described in the foregoing lines.

The post-Tertiary geological history of Hokkaidô has been marked at intervals by the formation of numerous conspicuous faults and circular depressions, most of which are referred to calderas, with subsidiary folds. The most significant fault-lines have a north-south or north-north-west to south-south-east trend in central and western Hokkaidô. Among the circular depressions, Lake Sikotu,

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(1) T. NAGAO: The Cenozoic History of Western Hokkaidô, with Special Reference to the Periods of Volcanism. Proc. Fifth Pacif. Sci. Congr., Victoria and Vancouver, Canada, 1933.

Lake Tôya, and the Akaigawa depression in western Hokkaidô and Lake Masyû and Lake Kussyaro in eastern Hokkaidô are best known. The great circular Volcano Bay is sometimes referred to as a depression. Intense and repeated eruptions of many post-Tertiary volcanoes were also significant feature in the history of the island. The latest separation of central Hokkaidô from Sagalien on one hand, and that of western Hokkaidô from Honsyû on the other, are also attributed to one of the post-Tertiary movements.

One of the most significant post-Tertiary events was the appearance of Sapporo-Tomakomai or Isikari Depression.<sup>(1)</sup> The initial depression resulted from the pre-Takikawa orogenic movement and filled with the Takikawa bed of the late Tertiary age, was later dried up, then became a scene of disturbance in the post-Tertiary or post-Takikawa time. Along the eastern and northern margins of the Isikari Depression, occurs the folded and tilted Takikawa, while this complex is not preserved on the western side of the depression, the uplifted flat-topped surface completed in the post-Setana planation being there extensively developed at an altitude sometimes exceeding 1000 meters above sea-level.

The present depression itself is filled with post-Tertiary sedimentaries and volcanic detritus. The oldest formation exposed within the trough is the Pleistocene Nopporo bed with some fossiliferous layers, consisting of marine and also probably estuarine deposits. This Nopporo bed extends beyond the depression, overlapping the older rocks. Although no superposition of the Takikawa and the Nopporo is observable, a distinct angular unconformity is safely supposed, the former being tilted and the latter nearly horizontal. Thus the Nopporo indicates the marine invasion into the depression which subsequently emerged to the present state. The line of demarkation on the eastern boundary of the trough is traced northward, and represented by a physiographically distinct fault-line which separates the western margin of the Tertiary area from the broad flood plain of the Isikari river and is covered by numerous fans and terraces of later date.

The post-Takikawa diastrophic movement was also one of the most conspicuous events in eastern Hokkaidô.<sup>(2)</sup> In this part of the

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(1) T. NAGAO: The Cenozoic History around the Sapporo-Tomakomai Depression (in Japanese). Journ. Geol. Soc. Japan, Vol. 43, 1936.

(2) T. NAGAO: The Cenozoic History of Western Hokkaidô, etc. Op. cit., 1933.

island, the Neogene rocks with associated volcanics are widely distributed, covering the Palaeozoic of subordinate extension and the Mesozoic(?) of very small area. Around Nokkeusi in southern Kitami, the Palaeozoic rocks are exposed as several elongate parallel horsts of a NE-SW trend; these are separated from one another by corresponding parallel troughs which are composed of the Neogene formations and filled with horizontal strata of the post-Tertiary age. As the equivalent of the Takikawa is closely associated with the underlying Neogene rocks and involved in this structure, it is evident that no great orogenic movement took place at the pre-Takikawa time and that this arrangement appeared as the result of the post-Takikawa diastrophism and subsequent erosion. The Siretoko and Nemuro peninsulas, which are stretched north-east or north-north-east-ward from the eastern extremity of the island presumably represent two of the similar horsts. It is remarkable, moreover, that this north-east direction of the leading structure in this region coincides with the general trend of the Tisima (Kurile) Islands. These islands, forming the northern festoon of the Japanese Archipelago, with the convex side toward the oceanic deep, consist of Tertiary tuffs and agglomerates with subordinate normal sedimentaries, which overlies the basement complex of granitic or dioritic rocks of the pre-Tertiary age, and are covered with post-Tertiary young volcanics. In the Island of Sikotan,<sup>(1)</sup> one of the islands of the South Tisima, parallel faults of a north-east to south-west trend are clearly observable. The Upper Cretaceous sedimentaries and the Tertiary volcanics, together with older intrusive rocks, are arranged in several parallel troughs and horsts and fringed by the late Pleistocene terraces. Moreover, according to Mr. SASA, in Kusiro (Kushiro) on the main island of Hokkaidô, the Palaeogene formations suffered folding and faulting and underlie the Pleistocene littoral deposits, the Kusiro series, with a distinct unconformity. The disturbance of the late Tertiary or early Pleistocene age is thus indicated in this area and in the Tisima Islands. The Kusiro series points the Pleistocene transgression on the uplifted and subsequently submerged Tertiary land area, parallel with that of the Nopporo bed in the Isikari Depression referred to before.

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(1) Y. SASA: A Preliminary Note on the Geology of the Island of Sikotan, South Tisima (South Kurile Island). Proc. Fifth Pacific Sci. Congr., Victoria and Vancouver, Canada, 1933.