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The Permian and Triassic Boundary at Thini Khola, Thakkhola Region, Central Nepal

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Abstract

The Permian and Triassic boundary was examined at Thini Khola area and precise columnar sections were obtained at three localities. The succession near the Permian and Triassic boundary is divisible into the calcareous sandstone part of the lower, orange dolomite part of the middle and thin-bedded limestones with mudstone seams of the upper, and the Permian and Triassic boundary is reasonably drawn between the middle and upper parts on the basis of already known occurrences of ammonites and newly found some conodonts. It was also discussed that extreme shallowing and regression of the sea at the end of the Permian occurred in most Tethyan realm and that transgression at the biginning of the Triassic was rather uniform and simultaneous.

1. Introduction

The Permian and Triassic (P–T) Boundary in the Himalayas has recently been reviewed mainly from sedimentologic viewpoints by KAPOOR and TOKUOKA (1985), who referred briefly to the boundary at Thini Khola (River) in the Thakkhola region on the basis of the present writer's unpublished data. The purpose of this paper is to present 1982 field work data, which are part of the results of the research team for "*The Crustal Deformation of the Nepal Himalayas*". The writer has been engaged in the study of the P–T boundary in the Tethyan realm since 1969 as a member of the Japanese Expedition Team (NAKAZAWA *et al.*, 1975; Iranian-Japanese Research Group, 1981; Pakistani-Japanese Research Group, 1985; etc.). Although the present study is not complete, it is worth describing the data with respect to future study.

The geology of the Thakkhola region was first discussed in the pioneer work of HAGEN (1968), which was followed by BODENHOUSEN and EGELER (1971), FUCHS (1967, 1977), FUCHS and FRANK (1970) and BORDET *et al.* (1971). BODENHOUSEN *et al.* (1964) first defined the P–T boundary at Thini Khola, where the Thini Chu Formation is overlain by the Triassic Thinigaon Formation. BORDET *et al.* (1971) published a detailed geologic map of this area on a scale of 1: 75,000 and reported that the Thini Chu Formation (Upper Carboniferous and Permian) consisted of sandstone and slate with some brachiopods, corals, fenestellid and crinoids, concordantly overlain by Triassic sediments mainly consisting of slaty rocks with numerous, but badly preserved, ammonoids and other molluscan fossils. BASSOULLET and COLCHEN (1977) named the Carboniferous and Permian strata the Upper Thini Chu and Lower Thini Chu Formations, respectively. *Otoceras* aff. *woodwardi* has been discovered from thin-bedded limestone and the P–T boundary was thus confirmed at its base. WATERHOUSE (1979), subsequent to his study in the Dolpo region (WATERHOUSE, 1977, 1978), checked the boundary of the area. He differentiated the Permian Namlang Group from the Carboniferous Thini Chu Group and showed that the Permian strata are either very thin or lacking in this area. Recently CLARK and HATLEBERG (1983) reported Lower Triassic conodonts from this area.

2. Description of the strata near the Permian and Triassic Boundary at Thini Khola

The Permian and Triassic strata are distributed along Thini Khola roughly in an E–W trend (Fig. 1). Unfortunately, the strata have been disturbed severely throughout the area, and precise geologic successions cannot be obtained. The P–T boundary could only be observed at three localities shown in Fig. 1. One is on a mountain slope 250 m southeast of Thinigaon (Loc. Th–A in Fig. 1) and the other two are along a small path to Thilicho Lake (Locs. Th–B and C in Fig. 1, and Fig. 2).

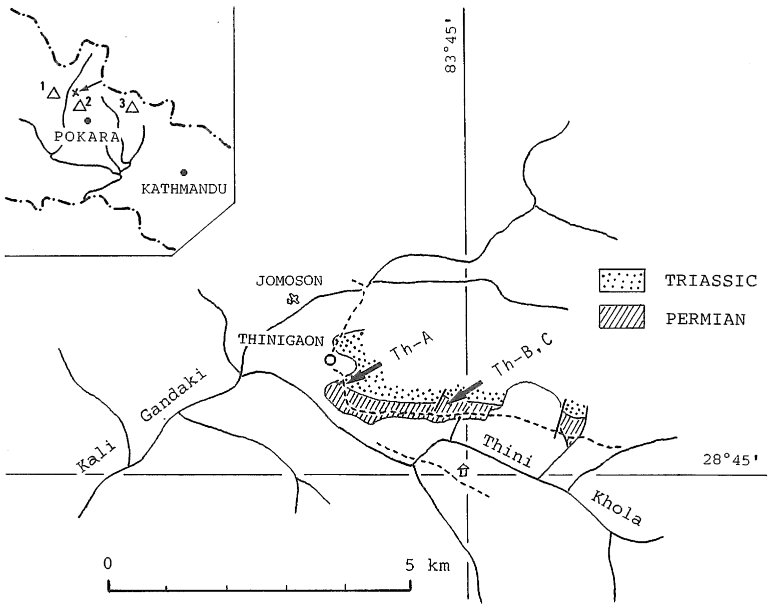

Fig. 1 Index map of the Thakkhola Region and Thini Khola
(1. Dhaulagiri, 2. Annapurna, 3. Manaslu)

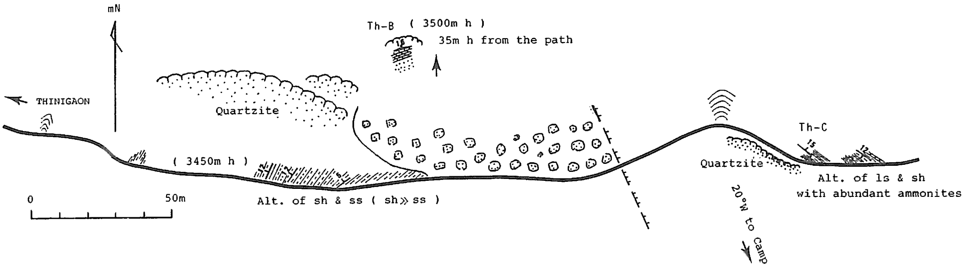

Fig. 2 Route map along the small path from Thinigaon to Tilicho Lake

Th–A Section

The Permian (?) strata are cropped out at high levels on the slope, while the Triassic strata are exposed at lower levels, between which are many ammonoid bearing limestone blocks, although no exposures are found (Plate I, Fig. 1). All strata along the slope dip gently southward, and are overturned. The columnar section of the area is shown in Fig. 3.

The stratigraphically lowest part, although mostly covered, is composed of slate succeeded by bedded quartzites in which are contained scattered shell fragments. Bed 1 consists of 20–50 cm bedded quartzites with abundant trace fossils which are about one centimetre in diameter, mostly perpendicular to the bedding plane. Beds 2, 3 and 4 are calcite-cemented quartzites and/or quartzitic sandstones with brachiopod fragments. Under the microscope, most quartz grains are observed to be limonite-stained. The strata between Beds 4 and 5, which are unfortunately covered completely, are inferred from many float blocks to be composed of alternating limestone and shale, the thickness of which are expected to be 50 m, if there is no dislocation or deformation between them. Lower Triassic ammonoids, although poorly preserved, are frequently found in these blocks. Bed 5 is a faintly parallel-laminated limestone, which is partly dolomitized. Ammonites are common in this bed (Plate I, Fig. 3). The stratigraphically overlying beds are composed of black shale, showing a greenish tint when altered, rarely intercalated with 2–5 cm limestone layers. Red shale 50 cm thick is also intercalated in the upper part. Beds 6, 7 and 8 are 10–20 cm bedded limestones with common ammonites. The former two are partly dolomitized. Bed 9 consists of 10–20 cm irregularly bedded limestones. These are micritic and are partly recrystallized. Bed 10, reddish in color, is a series of nodular bedded limestone. Thin-shell fragments probably of ammonoids, are observed under the microscope. Beds 11–14 are irregularly bedded, grey micritic limestones containing ammonoid-like fragments.

Th–B Section

Th–B is located along the path from Thinigaon to Tilicho Lake, and is 3450 m in

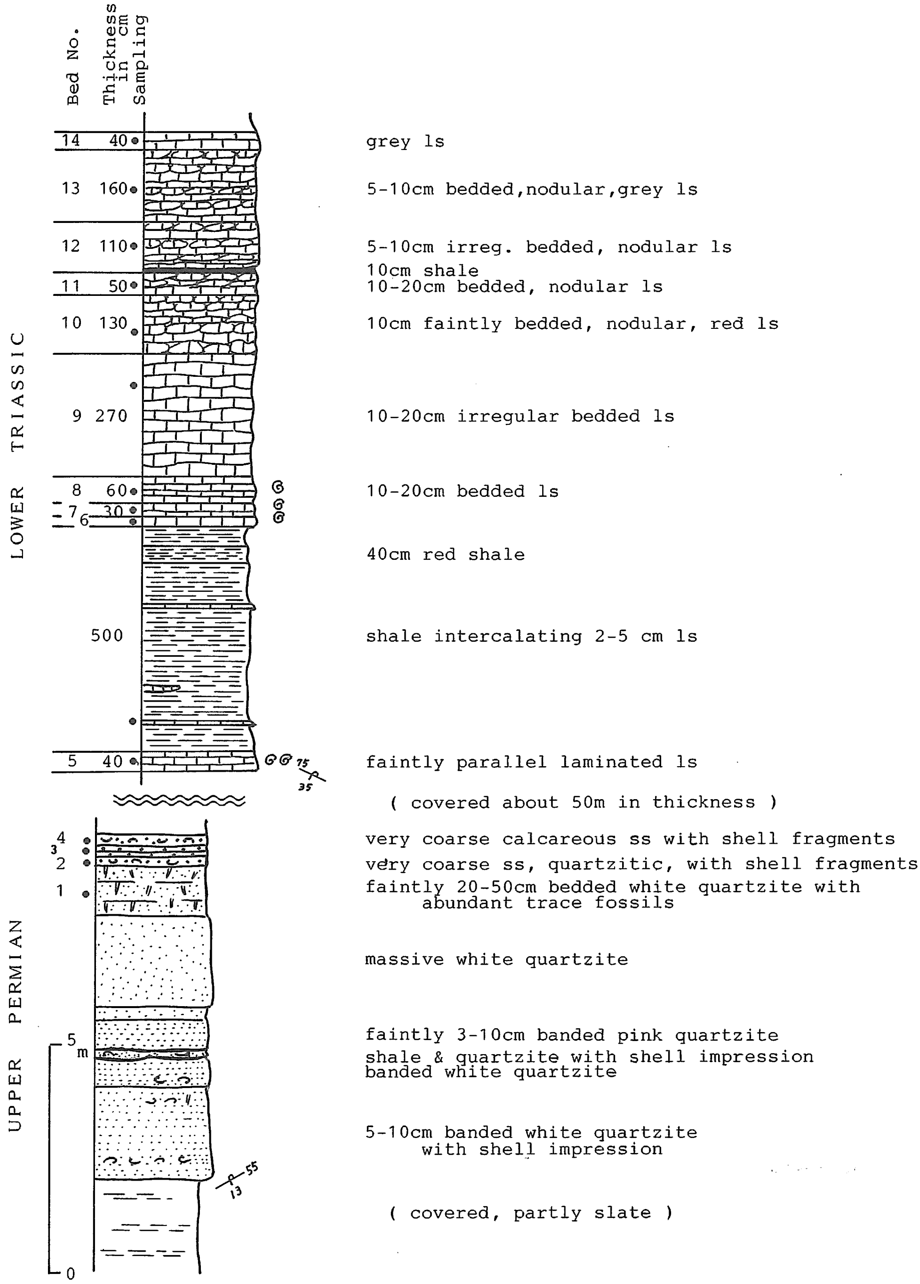

Fig. 3 Columnar section of the Permian and Triassic strata at Loc Th-A.

height. It takes about one hour on foot from Thinigaon. Along the path are distributed alternating slate and sandstone of unknown (although probably Permian) age. This locality, and Th–C as well, closely correspond to those place studied by BASSOULLET and COLCHEN (1977) and WATERHOUSE (1979). As shown in Fig. 2 and Plate II (upper left), the P–T boundary is well exposed about 35 metres above the path, where the Permian quartzites and calcareous sandstones are overlain by Lower Triassic thin-bedded limestones. At this locality, the P–T boundary could be precisely examined. The columnar section is shown in Fig. 4. The strata are lithologically divisible into the lower (Beds 1 to 4), middle (Beds 5 and 6) and upper (Beds 7 to 16) parts.

Bed 1 is dark greenish, 20 cm thick very coarse calcite-cemented orthoquartzite with poorly preserved brachiopods. Constituent grains are mostly well-rounded quartz.

Bed 2 is 25 cm thick, comprising dark greenish, very coarse, calcite-cemented orthoquartzite with poorly preserved brachiopods (Plate II, Fig. 3). Shell-fragments are sorted, forming laminations and orthoquartzite pebbles are sometimes contained. Under the microscope, sand grains are mostly quartz, which are well rounded and iron-stained (Plate II, Fig. 3′).

Beds 3 and 4 are muddy, calcite-cemented quartzitic sandstones, dark green in color. Compared with the underlying beds, sandstones are finer and angular grains become predominant. Fragments of brachiopods are contained.

Bed 5 (40 cm thick) and Bed 6 (60 cm thick) are dense, orange dolomite (Plate II, Fig. 2). Brachiopods and crinoid stems are sporadically contained. Under the microscope, euhedral dolomite crystals are observed and no terrigenous grains are present (Plate II, Fig. 2′).

Bed 7 (10 cm) and Bed 8 (5 cm) are dense, orange dolomitic limestone in which no fossil remains are found. Beds 9 to 15 are 2–5 cm bedded limestones intercalated with thin shale layers (Plate II, Fig. 1). Under the microscope, limestones are recognized to be dolomitic and thin-shell fragments, probably of ammonoids, are contained (Plate II, Figs. 1′ and 1″).

Bed 16 is grey limestone 25 cm thick, in which several poorly preserved ammonites were discovered. Limestone is micritic and partly dolomitized and shell-fragments (again probably ammonoids) are common.

Th–C Section

Th–C is located along the path 140 m east of Th–B (Fig. 2 and Plate I, Fig. 4). The strata near the P–T boundary are not so well exposed, although nearly the same beds as those at Th–B outcrop. The columnar section is shown in Fig. 4. Beds 2, 3 and 4 coincide with the lower part and bed 5 to the middle part of Th–B, while the upper part seems to be lacking here as will be discussed later, on the basis of conodont biostratigraphy. Beds 6 to 11 are named tentatively the uppermost part.

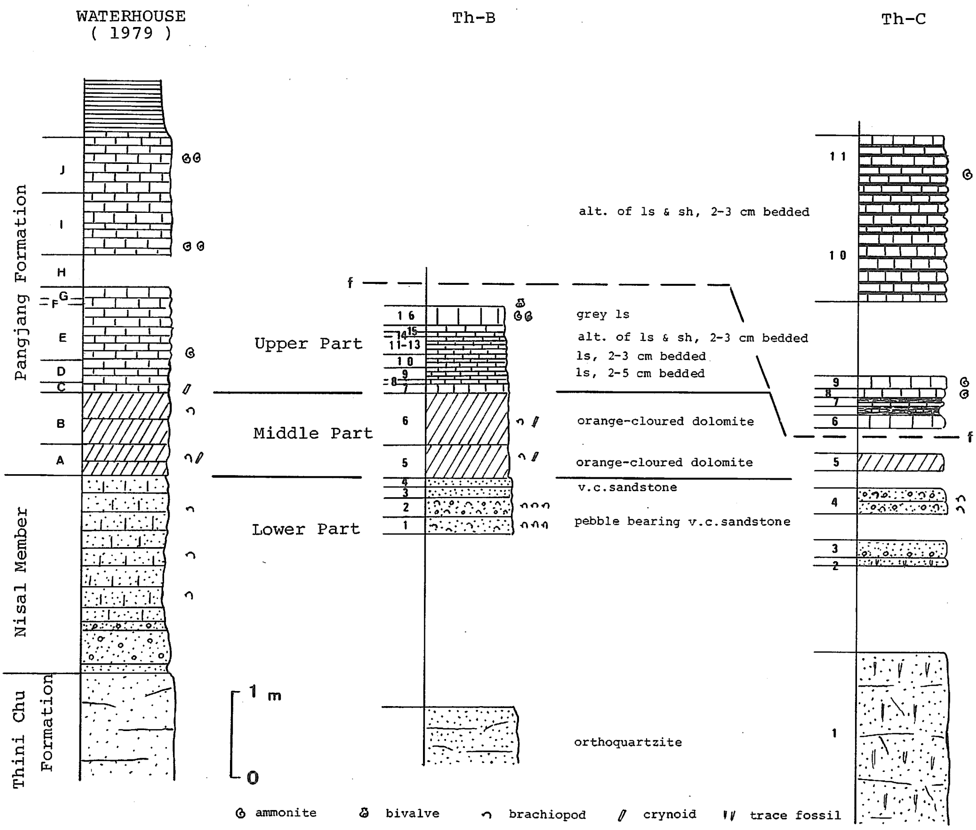

Fig. 4 Permian and Triassic boundary at Thini Khola. (Columnar sections of Th–B and Th–C are described in the present paper. The left column is reproduced from the data of WATERHOUSE, 1979.)

Bed 1 (more than 2 m thick) and Bed 2 (10 cm thick) are white quartzite with trace fossils which are perpendicular or slightly oblique to bedding. These beds can be correlated with Bed 1 of Section Th–A.

Bed 3 (20 cm) and Bed 4 (30 cm) are very coarse sandstone with sporadic pebble clasts of orthoquartzite.

Bed 4 is correlated with Bed 2 of Th–B. A well-preseverved brachiopod was discovered.

Bed 5 is composed of dense, orange dolomite, 20 cm in thickness, corresponding to bed 5 or 6 of Th–B.

Bed 6 is dense, orange limestone, 15 cm thick. No terrigenous grains are contained, while thick-shell fragments are commonly found.

Bed 7 is 4 cm dolomitic limestone, containing thick-shell fragments. The limestone is bordered above and below by mudstone.

Bed 8 is a 10 cm thick grey limestone. It is partly dolomitic and thin-shell fragments (probably of ammonoids) are contained along with thick-shell fragments.

Bed 9 is grey limestone, 15 cm thick, with poorly preserved ammonites. It is micritic and thin-shell fragments are contained.

Beds 10 and 11 are represented by alternating thin-bedded limestone and shale. Limestones are partly dolomitic and thin-shell fragments are contained.

3. Discussion of the Permian and Triassic boundary

At Thini Khola, BASSOULLET and COLCHEN (1977) discovered *Otoceras* aff. *woodwardi* from thin-bedded limestone (corresponding lithologically to the upper part of Th–B section described above), and concluded that the P–T boundary was located at the base of the limestone beds. They also reported *Ophiceras* cf. *chamunda* and *O.* aff. *serpentinum* from the same place. Following on from his precise study in the Dolpo region of western Nepal especially on brachiopods, WATERHOUSE (1979) examined the P–T boundary at Thini Khola. He reported that the Carboniferous Thini Chu Formation was overlain by the Permian Nisal Member (middle part of the Senja Formation), which, in turn, was overlain unconformably by the Panjang (Pangjang) Formation. In the Dolpo region, WATERHOUSE (1977 and 1978) restricted the Thini Chu Formation to Carboniferous strata and separated Permian strata as the Namlang Group which was divided into the Nangun, Senja and Pangjang Formations in ascending order. The Senja Formation was subdivided into several members including the Nisal Member. He noted that most parts of the Senja Formation were missing at Thini Khola. The Panjang Formation was characterized by vivid orange-red dense carbonates. The formation often yielded brachiopods (*Spiriferella*, *Neospirifer*, *?Transennatia*, *Linoproductus* and other productids) in the lower part and numerous ammonites in the upper part. His succession is reproduced in Fig. 4. The lower two units (A and B) seem to be correlated with the Pangjang Formation in the Dolpo region. It is worth mentioning here that *Otoceras concavum* has been reported from this formation in the Dolpo region with a number of productids by WATERHOUSE (1977). It is known that FUCHS (1977) reported *Otoceras woodwardi* and *Ophiceras* sp. from the lower 10 cm of the basal bed and *Ophiceras* sp. at 50 cm above the base.

The P–T boundary at Thini Khola was examined by the writer especially at Th–B and C sections (Fig. 4), both of which nearly correspond to the place examined by BASSOULLET and COLCHEN (1977) and WATERHOUSE (1979). The succession near the boundary is divisible into the lower, middle and upper parts. The layers underlying the lower part are composed of thick-bedded orthoquartzites, and may thus belong to the Thini Chu Formation of WATERHOUSE (1979). The lower part is composed of calcite-cemented orthoquartzites, in which well-rounded orthoquartzitic clasts are occasionally found. It contains fragments of brachiopods, sometimes concentrated in certain horizons, and is assigned to be a part of the Nisal Member of WATERHOUSE (1979). It is apparently of Permian age. The middle part is composed of dense orange dolomite, yielding fragments of brachiopods, bivalves and crinoids. The present writer could not find any ammonites, although a few ammonites have already been discovered as mentioned above. WATERHOUSE (1979) correlated this part (A and B) to the Pangjang Formation of the Dolpo region, and furthermore correlated it with Unit E1 of the Khunamuh Formation in Kashmir (NAKAZAWA *et al.*, 1975), although he included not only this part but also overlying parts in the Gangetian (late Dorashamian of his definition). Altnernatively NAKAZAWA *et al.* (1975) maintained that the top of Unit E1 represents the P–T boundary. This correlation seems to be reasonable if the problem where the P–T boundary should be drawn is ignored. The upper part consists of thin-bedded limestone in the lower half and thin alternating beds of limestone and shale in the upper half. Poorly preserved ammonites are rarely found in limestone, and under the microscope thin-shell fragments possibly of ammonites are commonly observed. This part is doubtlessly Lower Triassic.

Conodonts from the samples collected by the writer were checked by Dr. T. MATSUDA of Osaka City University, and are briefly discussed here. Precise description will be presented in the near future. In the upper part of Th–B, *Hindeodus minutus*, *H. parvus*, and *Gondolella carinata* are identified, while from the uppermost part of Th–C, *Neospathodus kummeli*, an index species of the Dienerian stage, and other conodonts have been discovered. On the basis of conodont biostratigraphy established in Kashmir by MATSUDA (1985), it is reasonable that the upper part of Th–B belongs

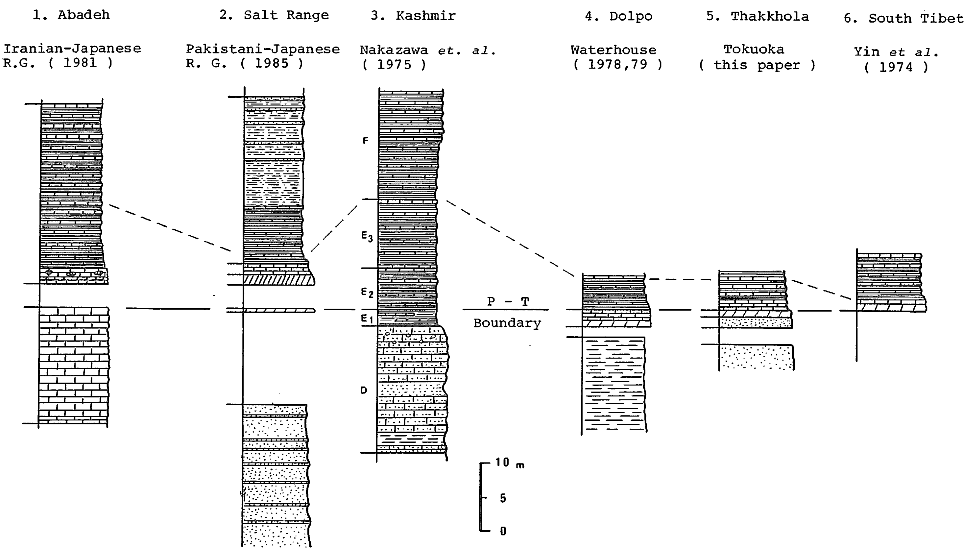

Fig. 5 Lithologic changes through the Permian and Triassic boundary at the representative places in the Tethyan realm (From KAPOOR and TOKUOKA, 1985).

to the Griesbachian stage and the uppermost part of Th–C is Dienerian. The middle part is very poor in conodonts, and only one specimen of *Gondollela* has been identified. Although conclusions are difficult to draw, it seems possible, as manifested by WATERHOUSE (1979), to correlate this part with Unit E1 of the Khunamuh formation in Kashmir. From Th–A, *Neospathodus* sp. cf. *N. waageni* (from Bed 5), *Neospathodus timorensis* (from Bed 14), etc. are found. Most parts of Th–A (Bed 5 and above) are likely to range from Smithian to Spathian.

It should be emphasized that an abrupt deepening of the Tethyan Sea in Central Nepal was started at the boundary between the middle and upper parts, which is well reflected in their lithofacies and the characteristics of carbonate rocks (Plate II). Although correlation has not been completely established, the middle and upper boundary may coinside with the Permian and Triassic boundary. As shown in Fig. 5, it has become apparent in the Tethyan realm, that extreme shallowing and regression of the sea at the end of the Permian occurred in most places, and that transgression at the beginning of the Triassic was rather uniform and simultaneous throughout.

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Explanation of Plate I

Fig. 1 Permian and Triassic strata cropping out at the mountain slope 250 m southeast of Thinigaon (Loc. Th–A).

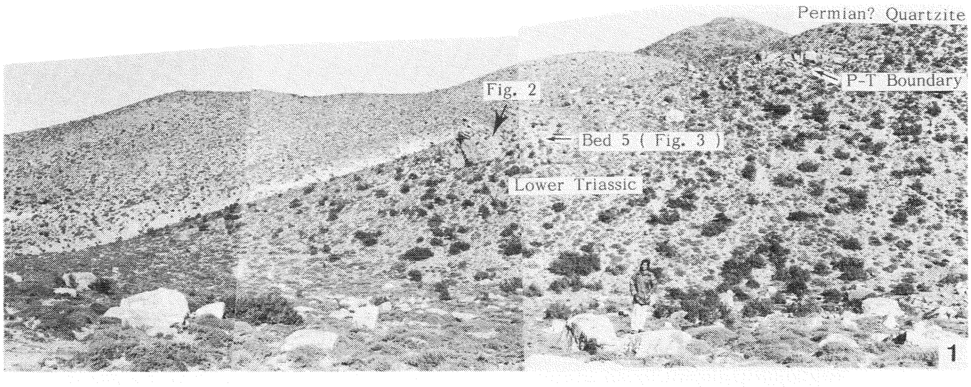
Fig. 2 Triassic strata at Th–A (from Bed 6 to Bed 14)

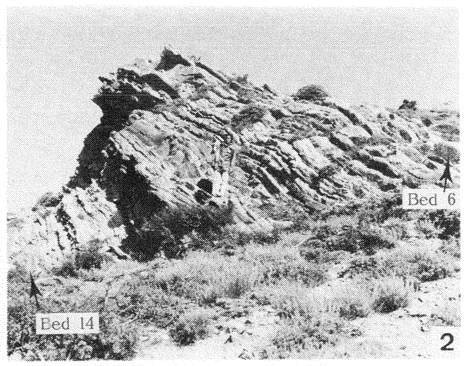
Fig. 3 Ill-preserved ammonites from Bed 5 of Th–A.

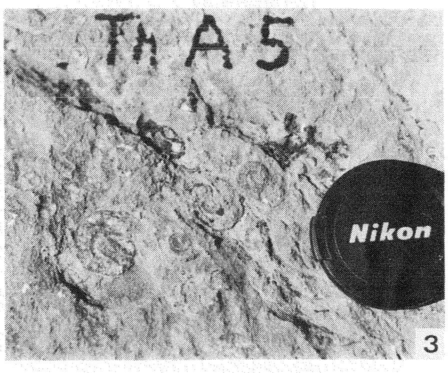
Fig. 4 Th–C section along the path. The P–T boundary is shown by an arrow.

Fig. 5 Close-up of the Permian and Triassic boundary at Th–C.

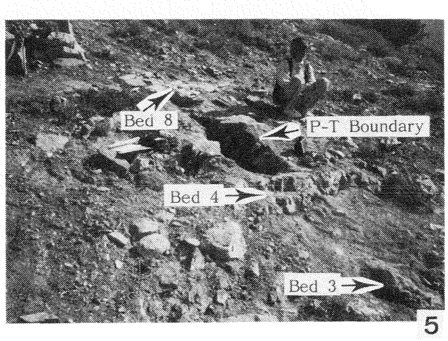
Plate I


Permian? Quartzite
P-T Boundary
Fig. 2
Bed 5 (Fig. 3)
Lower Triassic
1


Bed 6
Bed 14
2


Th A 5
Nikon
3


Th-C
Fig. 5
4


Bed 8
P-T Boundary
Bed 4
Bed 3
5

Explanation of Plate II

Top, left. An exposure of the Permian-Triassic boundary at Thini Khola (Th–B section). The boundary is shown by an arrow.

Figure 1. Thin-bedded alternation of limestone and shale of the Lower Triassic (the upper part) at Th–B section.

Figure 1′. Photomicrograph of limestone of the upper part (Bed 14). Thin shells of ammonites are contained in micritic matrix. Scale bar: 0.5 mm.

Figure 1″. Photomicrograph of limestone of the upper part (Bed 7). Thin shells are probably ammonite, rare thick ones probably brachiopods. Partly dolomitized. Scale bar: 0.5 mm.

Figure 2. Dense orange-colored dolomite of the middle part (Beds 5 and 6). The Permian-Triassic boundary is estimated between Beds 6 and 7.

Figure 2′. Photomicrogaph of dolomite of Bed 5. Thick shells of brachiopods are commonly contained. Scale bar: 0.5 mm.

Figure 3. Calcareous sandstones of the lower part (Beds 2, 3 and 4).

Figure 3′. Photomicrograph of calcareous sandstone (Bed 3). Calcite-cemented orthoquartzite brachiopod fragments. Quartz grains are mostly rounded or well-rounded. Scale bar: 0.5 mm.

Plate II