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Note on the Geology of the Markha–Nimaling Area in Ladakh (India)

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With 2 figures

India
Himalaya
Dras Unit
Ophiolitic Melange
Lamayuru Unit
Tso Morari Crystalline
Tibetan Zone

Summary

The paper deals with the ending of the Dras Unit, with the ophiolitic melange zone, Lamayuru Unit and their relations to the Nimaling Dome and Zanskar Synclinorium.

Thrusting of ultrabasics onto the Dras Unit led to sedimentation of a conglomerate horizon connecting the thrust masses. Post-Upper Paleocene molasse was deposited on the latter and the conglomerate. The lineaments terminating the Dras Unit join NE of Markha and continue southeastwards as one ophiolitic melange zone. The Lamayuru Unit is linked with the melange zone and passes southwestwards into the Triassic shelf carbonates. It also takes part in the metasedimentary succession of the Nimaling Dome. Thus the facies pattern along the continental margin is still preserved.

The litho-units of the Nimaling Dome and the sequence of the Khurnak Syncline adjoining in the SW are described. Palaeogeographically this area in NE-Zanskar was rather distant from the southern shore of the Tethys.

Zusammenfassung

Die Arbeit behandelt die Dras-Einheit, die NE von Markha ausspitzt, die ophiolitische Melangezone, Lamayuru-Einheit und deren Beziehung zum Nimaling-Dom und zur Tibet-Zone.

Die Aufschiebung von Ultrabasiten führte in der Dras-Einheit zur Ausbildung eines Konglomerathorizonts, der die einzelnen Gleitmassen verbindet, und darauffolgender Molassesedimentation (post-Oberes Paleozän). Die die Dras-Einheit begrenzenden Lineamente vereinigen sich NE von Markha und setzen als eine ophiolitische Melangezone gegen SE fort. Die Lamayuru-Einheit ist mit der Melangezone primär verbunden und leitet gegen SW in die triadischen Schelfkarbonate über. Sie nimmt außerdem Anteil an der Schichtfolge des Nimaling-Domes. Es sind somit in E-Zanskar die Fazien am Kontinentalrand in ihrem ursprünglichen Zusammenhang erhalten geblieben.

Die Litho-Einheiten des Nimaling-Domes sowie die im SW anschließende Khurnak-Mulde werden beschrieben. Paläogeographisch war dieses Gebiet vom S-Ufer der Tethys ziemlich entfernt.

Recent work by BAUD et al (1982 a,b ; 1983) led these authors to the view that the Tibetan Zone (s. l.) of eastern Zanskar was of allochthonous nature and consisted of several nappes. As this result is opposed to all my former experience, I extended my studies to the eastern part of Zanskar and started work along the Markha Valley, and in the Nimaling–Khurnak area. Though the material of the summer 1983 is not fully elaborated yet, some results of my survey are presented in this note. They concentrate on the melange Zone of the Markha Valley, the Lamayuru Unit and its relation to adjoining units, and the sedimentary cover of the Nimaling Crystalline.

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1. The Skiu Conglomerate and the Dras (Nindam) Unit

(Fig. 1, 2)

Coming from Ganda La one leaves the Jurutze Flysch of the Indus Molasse SW of Shingo. After a steep tectonic boundary the Dras Unit follows composed of green to dark grey sandstones, slates, lavas and tuffs several hundred meters thick (BAUD et al., 1982: Dras-Nindam Unit; BROOKFIELD & ANDREWS-SPEED, 1983: Khalsi Unit). At the top of the series there is a 50–80 m zone of bright red pebbly mudstone to conglomeratic sandstone succeeded by very thick-bedded to massive, green, coarse conglomerates. The components partly well-rounded are cherts, various carbonates, quartzites, sandstones, slates, basic volcanics and basic to ultrabasic plutonic rocks embedded in greenish silty matrix. The conglomerates pass into grey and green conglomeratic slates and are repeated by folding. BROOKFIELD & ANDREWS-SPEED (1983) take the conglomeratic series (150–200 m) as ophiolitic olistostrome and describe its gradation upwards into a molasse series. The latter consists of thick-bedded red, green and grey sandstone with conglomeratic and brecciaceous layers and slates. The named authors stress the mature character of this molasse sequence. They termed it the "Allochthonous Molasse".

I rather would name it autochthonous, because I found no tectonic break between the flysch-volcanic series (Dras-Nindam), the olistostromic beds and the succeeding molasse. The conglomerates, first observed by LYDEKKER (1883, p. 108), cross the Zanskar N of Chilling (STERNE, 1979) and join up with the ultrabasic mass WNW of Chilling. To the SE the conglomeratic horizon may be traced on satellite imagery to the northern ultrabasic body N of Chaluk. In my view the olistostrome horizon belongs tectonically to the Dras Unit. It is a marker for the thrusting of ultrabasic masses from the Indus Zone onto units adjacent to the S. The ultrabasics are not remnants of a continuous nappe, but are

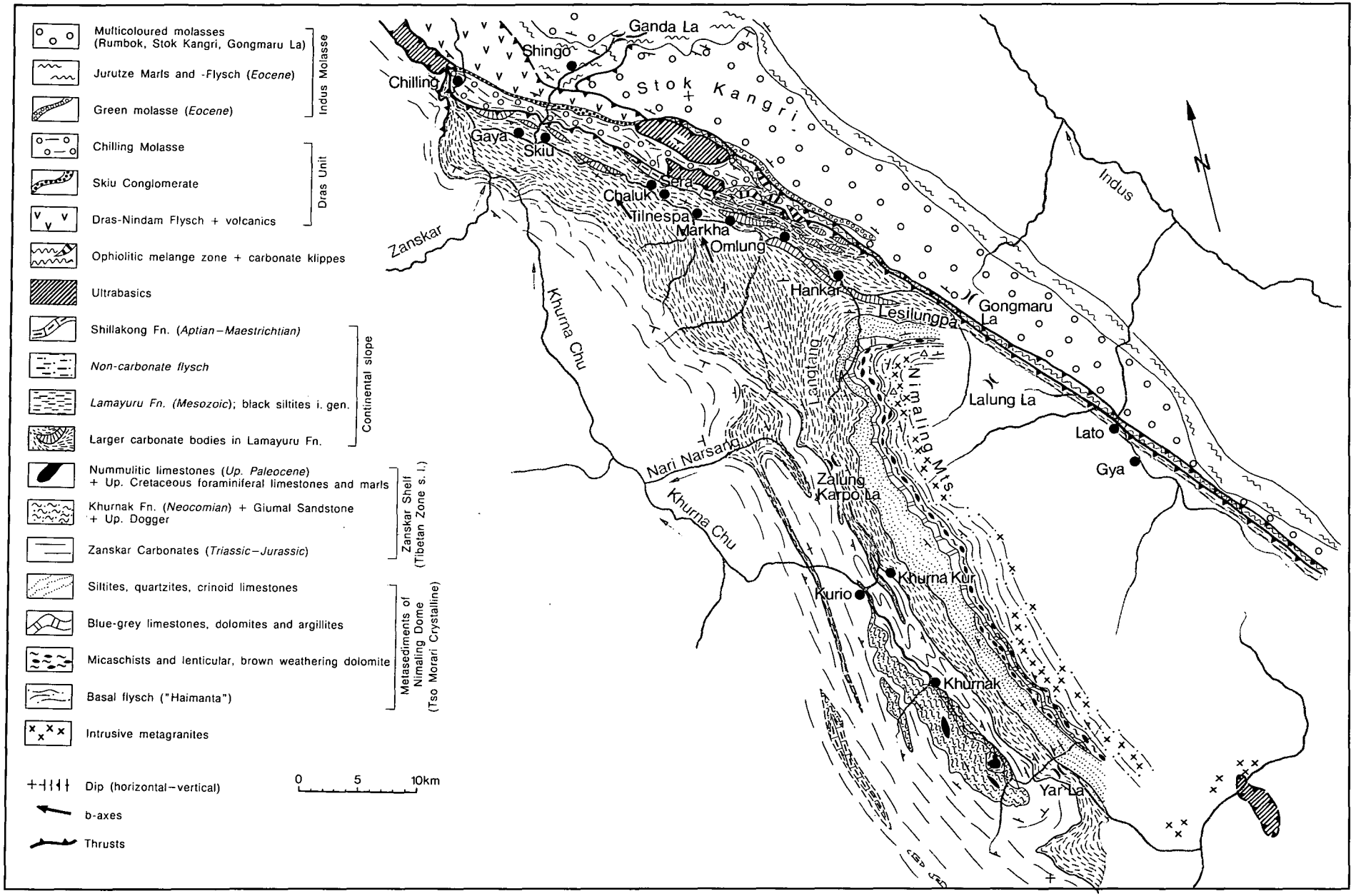

Fig. 1: The Geological Map of the Markha–Nimaling Area.

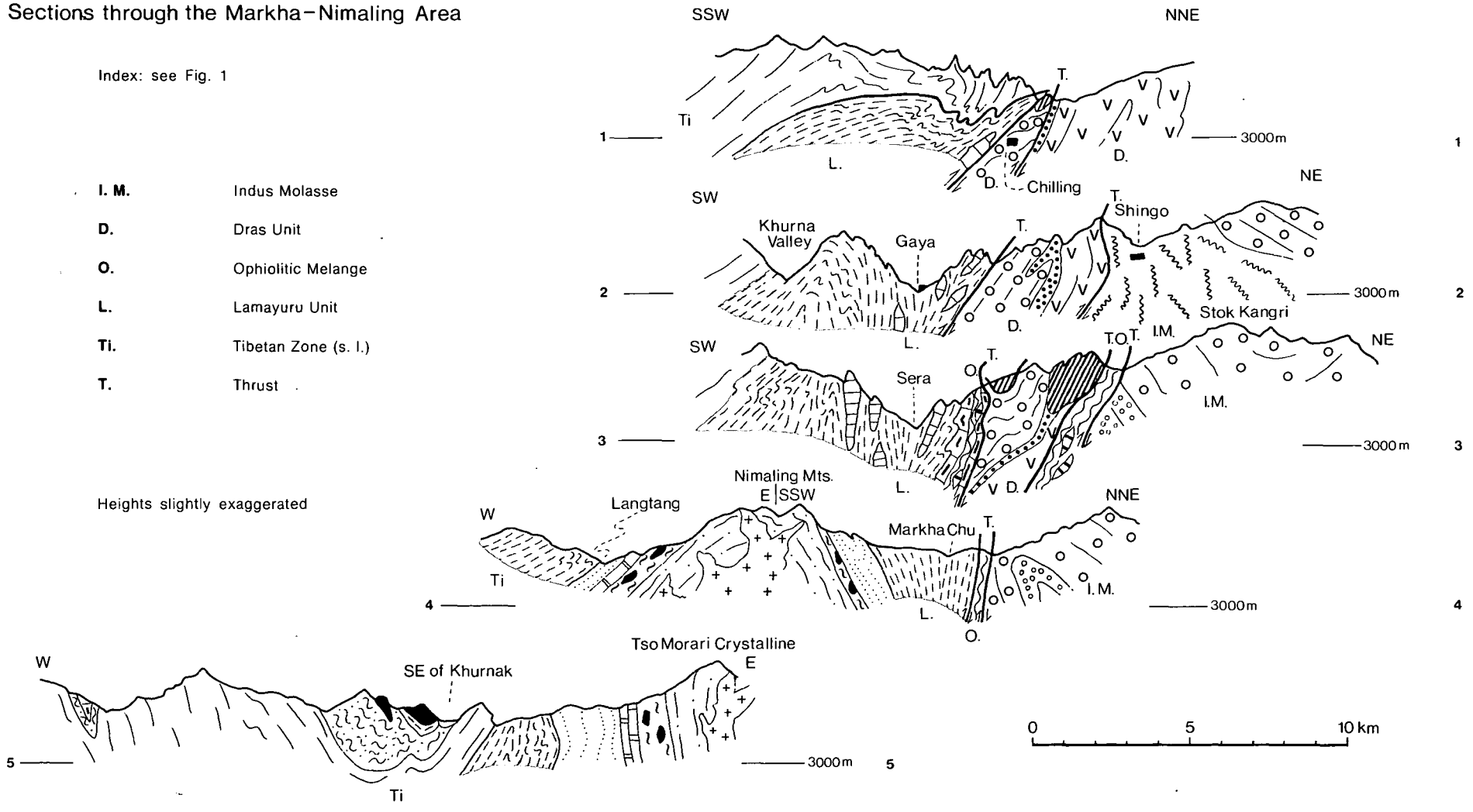

Fig. 2: Geological Sections through the Markha–Nimaling Area.

disconnected thrust masses (FUCHS, 1982). The basal red conglomeratic slates herald the approach of thrust sheets, whereas the green coarse conglomerates indicate their implacement; they were deposited as one continuous horizon connecting the isolated thrust masses. After this important event the conditions of sedimentation had changed to molasse type. The multicoloured molasse was deposited on the olistostrome or the ultrabasic thrust sheets respectively. Later movements brought ultrabasic masses locally to lie on top of the molasse (southern ultrabasic mass N of Chaluk). LYDEKKER (1883, p. 108) refers numerous nummulite bearing boulders in the conglomerates, whereas I observed them only in the overlying molasse series. In the latter a pebble from the Chilling area yielded *Nummulites* sp., *Rotalia* sp. and Alveolinas of the *elliptica* group suggesting Middle Eocene (?) age (kindly determined by Prof. Dr. L. HOTTINGER, Geol.-Palaeontolog. Inst. University Basle, Switzerland). Thus the post-Lower Eocene nappe tectonics (FUCHS, 1982) seem to have triggered the conglomerate sedimentation in the Dras Unit and the deposition of the succeeding molasse with reworking of Paleocene and Eocene limestones. The "Chilling Formation" (STERNE, 1979) is identical with the molasse dealt in this paragraph, a molasse deposited on the Dras-Nindam Flysch and on overthrust ultrabasics. I term this unit the Chilling Molasse .

This molasse pinches out between the branches of melange zones bifurcating NE of Markha. There the thrust planes separating the Chilling Molasse from the Lamayuru Unit and the Dras Unit from the Indus Molasse join up and continue eastwards as one ophiolitic melange zone. With the Chilling Molasse the whole Dras-Nindam Unit ends in eastern direction. In the area, where the named lineaments join up, a series of light-coloured limestone klippes occur in the melange zones, clearly visible on satellite imagery. Thus BAUD et al. (1982) are right showing the Dras-Nindam Unit end in the Markha-Omlung area.

2. The Melange Zone N of the Markha Valley

NE of the Tso Morari Crystalline there seems to be only one melange zone separating the Indus Molasse Belt from the Lamayuru Unit. It crosses the Leh–Manali Road at Lato (THAKUR & VIRDI, 1979). NE of Hankar the NE dipping Molasse sequence abuts along this lineament against the vertical rocks of the melange zone and the Lamayuru Unit. The melange zone is composed of flysch shales and sandstones, a conspicuous band of orange weathering coarse conglomerate, bright red argillites and cherts, and bodies of serpentinite or serpentinite conglomerate. The orange conglomerate mentioned above contains unsorted boulders and pebbles of carbonates, quartzites, cherts, basic volcanics and granite. Among the carbonates there are also foraminiferal limestones of Upper Paleocene age. Prof. Dr. L. HOTTINGER kindly determined:

Sample 83/19 (NE of Omlung):
Miscellanea sp. ?*Linderina* sp.
Daviesina cf. *danieli* SMOUT
Lockhartia conditi NUTTALL
Nummulites sp.
Discocyclinas
Truncorotalia
Age: Middle–Upper Paleocene (*primaeva-cuccuniformis*-Zone)

83/22 (NE of Hankar):
Alveolina "ovicula" NUTTALL →
A. decipiens or *leupoldi* gr.
A. (Glomalveolina) lepidula SCHWAGER
Nummulites ex gr. *globulus* LEYM.
Assilina sp.
Lockhartia sp.
small Rotalias
Miliolids
Valvulinids
various benthonic small foraminifers (indet.)
Age: Middle Ilerdian (Upper Paleocene)

83/24 (NE of Hankar):
Alveolina "ovicula" NUTTALL
A. (Glomalveolina) lepidula SCHWAGER
Orbitolites biplanus LEHMANN
Opertorbitolites sp.
Nummulites ex gr. *globulus*
Miliolids
Valvulinids
Age: Middle Ilerdian (Upper Paleocene)

This proves the post-Upper Paleocene age of the conglomerate. Probably this conglomerate in the melange zone also is the product of the Eocene nappe tectonics, which caused reworking of the Upper Paleocene limestones of Zanskar.

North of Omlung and Markha large klippes are found in the melange zone, which are composed of white and grey, rather massive limestone; attached to them there are also some minor red limestones (binocular observ.). The limestones are intruded by the associated green, grey and purple lavas. There are also volcanic slates, radiolarites, slates, silt- and limestones, and pebbly argillites of flysch facies, serpentinites etc. These rocks are highly contorted and steeply dipping SW.

The melange zone bifurcates in the named area. One branch continues straight to the large ultrabasic mass N of Chaluk. In its continuation towards NW the thrust plane between the Dras Unit and Indus Molasse does not show melange character. The southern branch separates the Lamayuru Unit from the Chilling Molasse of the Dras Unit. This thrust too is not of melange type. Thus it appears that the lineament lost its melange character after splitting up. Still further NW in the Lamayuru area the melange zones are well developed (FUCHS, 1977, 1979).

3. The Lamayuru Unit and its relation to adjoining units

The Lamayuru Unit is composed of carbonaceous argillites, siltites, minor sandstones and bluish limestones. The latter are partly alternating with the slates, partly they form lenticular bodies up to kilometer dimensions. BASSOULLET et al. (1981) showed that these limestones slipped from the Zanskar Shelf into the Lamayuru basin in form of sedimentary klippes, olistostromes, grain flow, etc. They prove a Jurassic age whereas intercalation of Shillakong Formation in the Lamayuru Unit documents even Upper Cretaceous age (FUCHS, 1977, 1979). Thus the flyschoid basin facies lasted from the Triassic up to Cretaceous.

Structurally the Lamayuru Unit is separated by thrust planes from the Dras Unit as well as from the Zanskar Carbonates in western Ladakh. The overthrusting of the Zanskar Carbonates on the Lamayuru Unit is clearly

observed in the mountains W of Chilling. E of the Zanskar, however, there is a marked change: The carbonate-Lamayuru boundary bends far to the S, and becomes gradational. The Lamayuru rocks build up a vast terrain. Along the Markha Valley they are subvertical and towards the S they dip gently beneath the Zanskar Carbonates. This domal structure is related with the NW-plunge of the Tso Morari Crystalline in the Nimaling group (Fig. 1). BAUD et al. (1982 b,c) subdivided the black argillite-carbonate belt into the "Markha Unit", which they correlate with the Lamayuru Unit, and the "Schistes Lustres" (Langtang Group) of the Nimaling Unit. I neither found the tectonic plane shown by BAUD et al. between these two zones nor did I recognize difference in lithologies. The whole belt ist made up by only one unit, the Lamayuru Unit. In the Langtang–Nimaling area the unit branches. The northern band continues straight SE to Lato-Gya region, whereas the southern one follows the SW-flank of the Nimaling Crystalline SSE towards Sangdah and the More Plain. This was already recognized by LYDEKKER (1883, p. 166).

All along the northern boundary the Lamayuru Unit is terminated tectonically against adjacent units – the Chilling Molasse of the Dras Unit (from Chilling to NE of Markha), and the Indus Molasse Zone (E from Markha).

In the Sera–Markha–Omlung region bands of Shillakong Formation (Upper Cretaceous) are intercalated in the northern parts of the Lamayuru Unit. The multi-coloured Shillakong limestones and argillites are connected with basic volcanics and radiolaritic cherts of the adjoining melange zone. Further I observed a passage of the calcareous Lamayuru flysch facies northwards into non-calcareous flysch. The latter being partly conglomeratic, is associated with the basic volcanics and limestone klippes of the melange zone and with the Shillakong Formation and brecciaceous blue limestones of the Lamayuru Unit.

As the Lamayuru Unit is highly disturbed, it is hard to decide, whether the above flysch indicates a lateral facies change towards the still deeper water of the melange zone or if it represents higher stratigraphic portions of the Lamayuru Formation. The Shillakong Formation associated with the flysch yielded a Campanian fauna (the sample taken in the valley N of Omlung was kindly examined by Prof. Dr. L. HOTTINGER, Geol. Palaeont. Inst. Univ. Basle, Switzerland):

Gavelinella sp.
Hedbergella sp.
Heterohelicids
one- and two-carinated Globotruncanas
Lagenids
small Rotalias
small agglutinative foraminifers
Orbitoides douvillei (SILVESTRI)
fragments of *Inoceramus*, bryozoans, echinoderms etc.

This and the association with the basic volcanics supports the second above alternative. Anyhow the Lamayuru Unit was directly adjoining the ophiolitic melange zone.

In the S it is difficult to draw a sharp boundary between the Lamayuru Unit and the overlying carbonates of the Zanskar shelf. Numerous carbonate bands are found interbedded in the argillites, as can be observed in the valley SW of Tilnespa. A tectonic boundary cannot be recognized in eastern Zanskar and a passage seems to be indicated: Towards the SW carbonates intertonguing with the argillites become more and more frequent. Thus the passage zone between the shelf and the continental slope (Lamayuru) is preserved in eastern Zanskar, whereas in western Zanskar it was disturbed by intensive thrusting.

The Lamayuru Unit is linked not only with the sediments of the Zanskar shelf in the S and the melange zone in the N, but also with the Tso Morari Crystalline in the SE. In the NE the Lamayuru Formation overlies stratigraphically the Palaeozoic metasediments of this crystalline dome; in the W and SW it takes the same position and is succeeded by Kioto Limestone (Upper Noric–Lower Dogger) and a sequence ranging up to the Upper Paleocene. This succession, beautifully exposed in the Khurnak Syncline, belongs to the Zanskar Synclinorium (Tibetan Zone s. l.). In the sequence mentioned the Lamayuru rocks represent mainly the Triassic portion, whereas their stratigraphic range seems to increase considerably towards the NE (Triassic–Cretaceous).

4. The Metasedimentary Succession of the Nimaling Dome

From the Tso Morari (Tso = lake) in Rupshu a huge crystalline uplift reaches NW towards the Nimaling Group, where it plunges under its sedimentary cover. According to THAKUR & VIRDI (1979) the core of this dome is composed of high-grade metamorphics (Puga Fn.) passing into the low-grade metamorphic series of the flanks (Thaglang La Fn.). Both formations are intruded by granites. VIRDI et al. (1978) discovered mega- and microfossils in the carbonates of the Thaglang La Formation documenting a Permian age. The description of the high-grade crystallines (garnet-, kyanite-, sillimanite gneisses) reminds of the Central Crystalline, which also grades into metasediments of Phanerozoic age.

Though I touched the Nimaling Mountains only marginally, it may be concluded from the boulders of the rivers that the high grade crystallines are not exposed there. The higher elevated central parts of the Nimaling Group are built up by coarse granite-gneisses intrusive into a thick flysch complex: fine-grained metasandstones, -siltstones and argillites of dark grey, green colour form a rhythmic alternation. Graded bedding, ripple cross-laminations , load convolutions, disturbed bedding, burrows, flute casts give the thick series (>1000 m) a distinct flysch character; ripple marks also are observed. The series has undergone greenschist metamorphism which, however, is not very much obvious due to the silty nature of the rocks. They disintegrate to irregular blocks and exhibit dark, brown, weathering colour. I do not doubt that this typical trough formation corresponds to Haimantas, Martolis, Phe Formation, Dogra Slates and other Precambrian to Lower Palaeozoic series forming the base of the Tethys succession.

The basal flysch is overlain by light green-grey, shining phyllitic micaschists containing lenticular bodies of deep brown weathering, grey dolomite. The thickness of that series varies between 150 and 800 m. Small bodies of metagabbro intruded the above beds in the Langtang area. According to personal communication by Prof. W. FRANK (Geol. Inst. Univ. Vienna) similar dolomites underlie the Ordovician conglomerates in south-eastern Zanskar. They seem to correspond with the Parahio Series of Spiti.

Above the micaschists and dolomite lenses a carbonate formation follows varying between 150–600 m thickness. Blue and blue-white banded limestones predominate but there are also dark phyllitic schists, calc phyllites, calc-micaschists, light coloured dolomites and carbonate quartzites. Generally the carbonates are recrystallized and the s-planes may be coated by thin phyllite. The formation appears in the landscape as an ochre-coloured band.

ENE of Khurnak the above carbonates are succeeded again by micaschists and ochre weathering dolomite bodies; this repetition may be stratigraphic or tectonic.

Normally the carbonate formation passes upwards into a 250–1200 m thick series consisting of silty or sandy argillites, quartzites and sporadic crinoid limestones. The argillites are grey to dark grey phyllites, slates and grade into schistose siltstones. The quartzites are commonly coarse-grained, locally fine-brecciaceous and show schistosity; they are white, yellowish, grey and generally thick-bedded. The quartzites occur as bands 5 to 30 m thick. The limestones, frequently impure, show grey or bluish colour; crinoids are rather common. The boundary against the Lamayuru Formation, which follows stratigraphically is not easy to draw. The latter is distinguished by the absence of the quartzites, the regular alternation of dark argillite and blue limestone and the reduction of sandy-silty material in the argillites.

It appears that the whole succession of formations described corresponds with the Thaglang La Formation of VIRDI et al. (1978), and unfortunately it is not clear from which carbonates the Permian fauna was derived. I am rather certain about the Precambrian–Early Palaeozoic age of the basal flysch to micaschist-dolomite sequence. The overlying series are Palaeozoic and I suppose that the boundary at the base of the Lamayuru Formation coincides with the Palaeozoic-Mesozoic boundary. Further treatment of my samples may bring light on that problem.

5. The Stratigraphy of the Tibetan Zone (s. l.) in the Khurnak area

The mainly Palaeozoic sequence described in the preceding chapter is stratigraphically overlain by several hundred meters thick Lamayuru Formation. This series which yielded crinoids only seems to represent the larger portion of the Triassic. It is succeeded by a thick development of the Kioto Limestone. Near the place Kurio the typical shell beds with *Megalodon* and *Dicerocardium* respectively with *Lithiotis* were observed in the thick-bedded limestone series. There are also frequent crinoids, corals, etc. In upper Khurnak the Kioto Limestone is followed by 25–30 m of ochre weathering blue crinoid limestones, impure sandy limestones and marls, apparently representing the Upper Dogger; belemnites are not rare in the ferruginous series.

The Spiti Shales were not observed and seem to be missing. Above the Dogger and where the latter is missing directly on the Kioto Limestone, a thick ochre weathering flyschoid series follows. In some places the lowest 30–50 m consist of dark grey, greenish, fine-grained sandstones with layers of siltstone and silty slate. These rocks disintegrate to irregular fragments and show rusty weathering colour. The lithology resembles the Giumal Sandstone, the medium- and coarse-grained sandstones, quartzites, breccias, however, are missing.

The main mass of the flyschoid formation being several hundreds of meters thick, consists of dark grey or greenish siltstone and silty slate, fine-grained sandstone, which is not predominating as in the described Giumal Sandstone, carbonatic-silty argillite and rare blue, impure limestone. S-planes are uneven and show burrows, zoophycus and other hieroglyphs. The rocks weather to irregular ochre coloured fragments. A few crinoids and belemnites were the only fossils found. The series characterised by soft geomorphological forms, reminds of the Kangi La Flysch, for which it was mistaken by me in the field. After the determination of the overlying foraminiferal marls and limestones as Turonian to Maestrichtian it is clear that there can not be correspondence in age, because the Kangi La Flysch is Campanian to Lower Maestrichtian (FUCHS, 1982, p. 9). The series of the Khurnak area thus is pre-Turonian, probably Lower to Middle Cretaceous, and represents a finer-grained facies of the Giumal Sandstone more distant from shore. The term Khurnak Formation is introduced for the series.

In a squeezed syncline SSE of Khurnak village the described flyschoid series is followed by light red, grey or green limestones to slaty marls ca. 15 m thick. The numerous foraminifers were recognizable already in the field. Dr. R. OBERHAUSER (Geologische Bundesanstalt Vienna) kindly determined (83/38):

Praeglobotruncana ex gr. *helvetica* BOLLI (frequent)
Praeglobotruncana div. sp.
cf. *Rugoglobigerina*
small Hedbergellas
cf. *Rotalipora*

Though *Globigerina helvetica* is not entirely identical with the forms of the Seewer Limestone of the Helveticum or the Austroalpine Turonian shales of the Alps, a Turonian age is suggested.

83/39:

Rotalipora turonica thomei HAGN
Globotruncana aff. *sigali* REICHEL
Praeglobotruncana ex aff. *praehelvetica* (TRUJILLO)–*helvetica* (BOLLI) (transitional forms)
Globotruncana div. sp. (partly beginning development of double carinae)
small Hedbergellas
cf. *Schackoina*
Age: Cenomanian may be excluded, Turonian is suggested.

Fallen blocks show that there are also Upper Paleocene limestones associated with the above Cretaceous beds.

In the core of the Khurnak Syncline, not far from the above outcrops, lithologically very similar foraminiferal limestones and marls are underlain by black silty slates containing sporadic dm-layers of impure carbonate. These black slates contain large concretions and yielded no determinable fossils. The thickness of that rusty weathering series attains several tens of meters.

The black slates are overlain by white, cream and grey limestones, marls and marly slates also several tens of meters thick. In these rocks rich in foraminifers Dr. R. OBERHAUSER kindly identified:

83/43:

Globotruncana ex gr. *elevata* BROTZEN
Globotruncana aff. *concavata* BROTZEN
other single and double carinated Globotruncanas
small Heterohelicids
Age: higher parts of Upper Cretaceous, most probably Lower Campanian.

83/44:

Globotruncana ex gr. *stuarti* (LAP.)
double carinated Globotruncanas (div. sp.)
Age: Campanian–Maestrichtian

83/46:

Globotruncana ex gr. *lapparenti* BROTZEN
Globotruncana (div. sp.)

As flat-spiral, double carinated Globotruncanas prevail, Santonian age is suggested (Coniacian and Campanian can not be excluded with certainty).

It appears to be significant that the foraminiferal limestones proved a Santonian to Maestrichtian age, where they overlie the black slates, and are of Turonian age, where they follow directly above the Khurnak Formation. This suggests that the black slates replace the pelagic carbonates in the lower Upper Cretaceous. As these facies differences are observed in a rather limited area, a complicated facies pattern is indicated.

The youngest beds in the sequence of the Khurnak Syncline are Upper Paleocene foraminiferal limestones. In one of the samples (83/45) these limestones are in direct contact with the Upper Cretaceous foraminiferal limestones, which either implies that there was a phase of non-deposition in the Lower and Middle Paleocene or some mechanical mixing occurred. The Tertiary limestones are blue or grey and generally show a brecciaceous structure. The "nummulites" are found in the fragments as well as in the calcareous matrix. The fragmentation may be related with gliding tectonics and starting nappe movements contemporaneous with sedimentation.

Prof. Dr. L. HOTTINGER (Geol. Pal. Inst. Univ. Basle, Switzerland) kindly determined in my samples:

83/40:

Alveolina "ovicula" NUTTALL
A. subpyrenaica LEYM or transitional form to *ilerdensis* HOTT.
A. sp. div., indet.
A. (Glomalv.) lepidula SCHWAGER
Orbitolites biplanus LEHMANN
Daviesina ruida (SCHWAGER)
Daviesina cf. *kathyaki* SMOUT
Lockhartia hunti pustulosa SMOUT
Dasycladaceas
Age: Middle Ilerdian (Upper Paleocene)

83/45:

Miscellanea cf. *miscella* (D'ARCH.)
Alveolina cf. *cylindrata* HOTT?
Kathina selveri SMOUT
Daviesina kathyaki SMOUT
Opertorbitolites sp.
?Nummulites = *Ranikothalia nuttalli* DAVIES (fragment)

In the same slide the above Lower to Middle Ilerdian (Up. Paleocene) limestone abuts against pelagic limestone containing Globotruncanas, Heterohelicids and small indet. benthonic foraminifers of Upper Cretaceous age.

It is to be emphasized, that with exception of 83/19 (Middle–Upper Paleocene) all my Paleocene samples taken in the course of the 1980 and 1983 expeditions are of Upper Paleocene age. This suggests a gap in the Lower and Middle Paleocene of Zanskar. GAETANI et al. (1983, p. 90) also conclude that there was a gap spanning the interval from Middle (?) and Late Maestrichtian to Late Paleocene.

6. Some Palaeogeographic Conclusions

The sequence of metasediments exposed in the Nimaling Dome resembles the succession of the southern limb of the Zanskar Synclinorium; the Crystalline of the Tso Morari Uplift seems to correspond to the Central Crystalline. So the Tso Morari Crystalline represents continental crust of the northernmost marginal parts of the Indian Continent. The fact that the Lamayuru Unit forms part of the sedimentary succession of the Nimaling Dome implies that it was deposited on continental crust. Considering the flyschoid character of the Lamayuru Unit it appears to be a deposit of the continental slope (FUCHS, 1982; BROOKFIELD & ANDREWS-SPEED, 1983). In the SW the Lamayuru Formation interfingers with the shelf sediments of Zanskar, whereas, in the NE it is linked with the ophiolitic melange zone; its northernmost parts close to the melange zone are characterised by non-calcareous flysch associated with basic volcanics, Shillakong Formation and interbedded radiolarian cherts; these portions may overlap the oceanic crust N of the continental slope. Thus the original facies pattern shelf – continental slope – ocean floor is still recognisable, because tectonization was not so strong in eastern Zanskar leaving the facies belts still connected.

In the Khurnak Syncline a stratigraphic record from the Precambrian to Upper Paleocene is exposed. As I hope that further treatment of my samles might elucidate the Palaeozoic stratigraphy, I shall only discuss the Meso-Cenozoic facies relations in this preliminary report. The new information from the Khurnak Syncline is valuable for palaeogeographic reconstruction because of its position in north-eastern Zanskar.

The major part of the Triassic is developed in euxinic flyschoid Lamayuru Facies, which gradually is replaced by shallow-water carbonates towards the SW. The Kioto Limestone (Upper Noric–Lower Dogger) shows uniform development throughout Zanskar. It slipped into the Lamayuru Basin and thus interfingers with the Lamayuru Formation (FUCHS, 1977, 1979; BASSOULLET et al., 1981). The ferruginous calcareous-arenaceous shallow-water facies of the Upper Dogger, locally developed, is missing in several sections. Spiti Shales were not observed. The Giumal Sandstone (Lower Cretaceous) occurs locally forming the basal part of the silty-argillaceous Khurnak Formation. There is clear indication of fining towards the NE, which agrees well with observations in western Zanskar (FUCHS, 1982; GAETANI et al., 1983). The terrigenous material was derived from the SW.

The Upper Cretaceous commences with pelagic formations: In SW-Zanskar the Cenomanian to Lower Campanian Chikkim Limestone is developed, whereas the multicoloured Shillakong Facies is confined to the N of western Zanskar. E of the Zanskar River the latter facies is found throughout Zanskar and has stratigraphic range from Upper Albian to Campa-

nian (BAUD et al., 1982 b; 1983; own data). The pelagic carbonates (Turonian–Maestrichtian) of the Khurnak area are poorer in argillites than the Shillakong Formation. Their lower parts (Turonian) are locally replaced by black shales (Lamayuru Facies?). FUCHS (1982) and GAETANI et al. (1983) accept sedimentation on a sill respectively a pelagic plateau for the Shillakong Facies. I suggest a similar environment for the Khurnak carbonates, probably even more distant from land; the black silty shales indicate a local SW-protrusion of the Lamayuru trough facies in the Turonian. The Maestrichtian overlap of Lamayuru Facies which was observed by FUCHS (1982) in western Zanskar is not indicated in the E. The Campanian to Lower Maestrichtian Kangi La Flysch and benthonic Upper Maestrichtian–Upper Paleocene Spanboth Formation are confined to SW Zanskar. In the Khurnak area the Maestrichtian pelagic carbonates are directly overlain by Upper Paleocene foraminiferal limestones corresponding to the Lingshet Limestones (FUCHS, 1982). Thus a gap in the Lower and Middle Paleocene is indicated (compare GAETANI et al., 1983). Abundant pebbles of Upper Paleocene limestones in conglomerates of the ophiolitic melange and various molasse series show that these carbonates were eroded apparently soon after their deposition.

The movement of the Nappes, which rest on Lower Eocene beds in the Spongtang area, start now (FUCHS, 1982). Lower Eocene, however, is not found in the Khurnak Syncline.

The nappe tectonics brought about a marked change in environment. In front of the Spongtang Klippe the non-marine, red and green Chulung La Slates were deposited (FUCHS, 1982). In the Dras Unit a conglomerate horizon connects isolated thrust masses of ultrabasics and sedimentation turned to molasse type. In the Indus Molasse Zone (s. l.) flysch sedimentation locally lasts into the Eocene (Jurutze Flysch, BROOKFIELD, 1981; BROOKFIELD & ANDREWS-SPEED, 1983) or is replaced by molasse type deposition. After another tectonic phase the folded Jurutze flysch is transgressed by younger multi-coloured molasse series (BROOKFIELD, 1981; own data). Younger thrusting reactivates ophiolitic melanges and former thrust planes. The Indus Molasse is deformed and partly overthrust by adjacent zones from the SW.

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