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The occurrence of Blueschists between the middle Indus and the Swat Valleys as evidence of subduction (North Pakistan)

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Geologia. — *The occurrence of Blueschists between the middle Indus and the Swat Valleys as evidence of subduction (North Pakistan).* Nota (*) del Socio ARDITO DESIO.

RIASSUNTO. — Viene segnalata la scoperta di scisti a glaucofane in due località nei pressi del passo Shangla, fra la media valle dell'Indo e la valle dello Swat, nel Pakistan Settentrionale.

Tale litotipo metamorfico affiora in vicinanza di una lunga linea di faglia che mette a contatto formazioni cretaceo–eoceniche con formazioni paleozoiche o più antiche.

La presenza della facies degli scisti blu (scisti a glaucofane) presso la faglia di Patan ed altri elementi, inducono a ipotizzare tale dislocazione come la traccia di un fenomeno di subduzione verificatosi nel Terziario. La faglia di Patan rappresenterebbe la prosecuzione occidentale della sutura dell'alto Indo interpretato da Gansser quale traccia della subduzione del continente indiano sotto il continente eurasiatico.

During my 1971 expedition to Northern Pakistan I scoured the Indus valley along the Karakorum Highway from Gilgit to the Swat valley and although I was obliged to travel very quickly because of the roadworks I collected a number of rock samples and drew a preliminary geological sketch-map of that area (Desio, 1974).

Among the samples examined and shortly described by my collaborator. F. Forcella, two of them are of particular interest. They are the sample 71 PD–36 collected at the Shangla Pass, on the watershed between the Indus and the Swat rivers (fig. 1) and classified as *chlorite–glaucophane schist*, and the sample 71 PD–26 collected downstream from Patan, near Dagh Qala, from the right bank of the Indus river and preliminarily classified as *hornblende eclogite*.

A more accurate investigation of the nature of the monocline pyroxene by diffractometric analysis revealed a low percentuage of the jadeite molecule and therefore the last rock is to be identified as a *basic granulite*. From Topsin (a site not far from the first locality) two samples of glaucophane schist, with and without garnet, were described for the first time in Pakistan by F.A. Shams (1972) [1].

According to Shams, the glaucophane-bearing rocks at Topsin are bounded by phyllite on one side and by quartzose micaschist on the other side, and in a south-westerly direction the rock body thins out and disappears under the

(*) Presentata nella seduta del 14 maggio 1977.

(1) The occurrence of glaucophane schists, which presently seams to be so rare in our territory, probably depends on the scarsity of petrological field investigations not only to the west, but also to the east of the Nanga Parbat-Haramosh massif, along the upper Indus suture line.

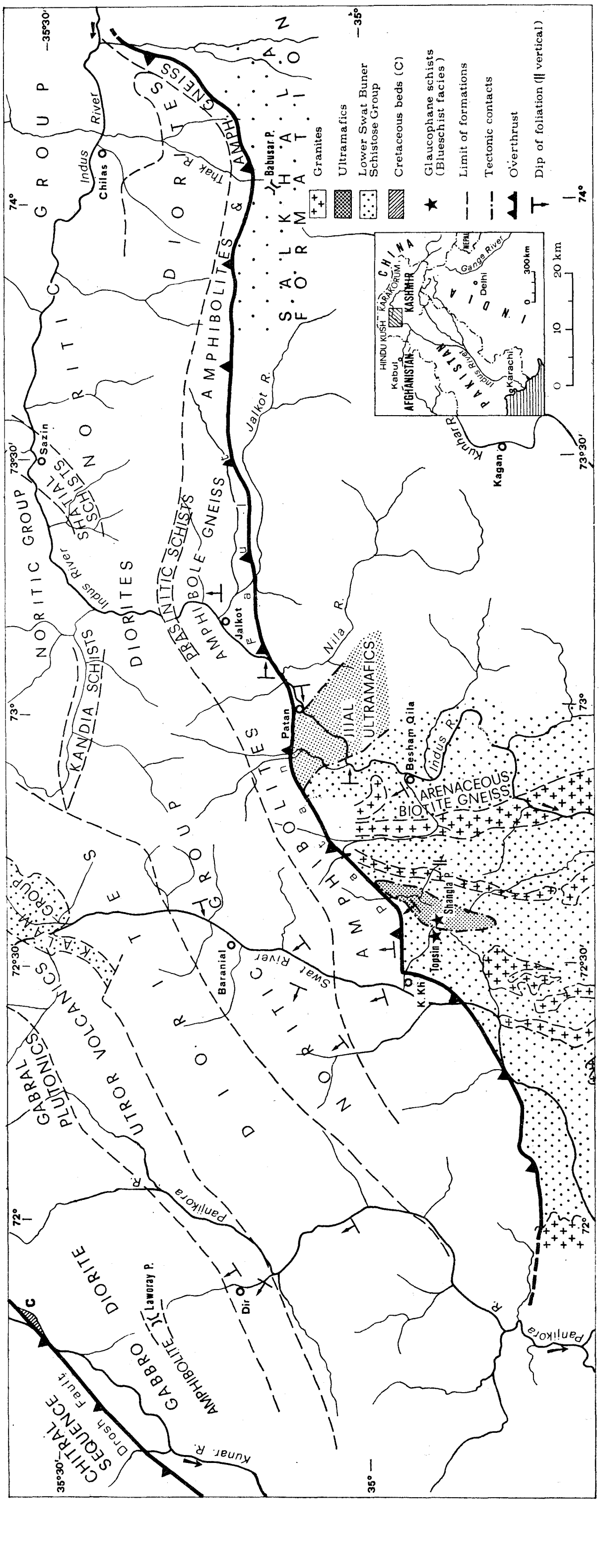

Fig. 1. – The Patan overthrust-line and the location of the glaucophane schist.

alluvial deposits of the Swat river: in the opposite direction it approaches the vicinity of a mass of alpine-type serpentinite.

The geologic situation of the Shangla pass is similar. A thick body of serpentinite with some biotitic gneiss and quartzose micaschist intercalations crosses the pass, coming from the Chamtalai valley, and continues toward the Shain valley (on the opposite slope of the pass) as far as downstream of the Alipurai bridge. The layering is evident near the bend of the river and plunges toward north-west with a medium inclination.

A layer of banded marbles several meters thick with micaschist and amphibolic schist intercalations crops out at the contact with the serpentinite complex and is immediately followed downstream by a thick layer of augen-gneiss dipping north-west. Arenaceous biotitic paragneiss plunging north-west succeeds downstream from the augengneiss and is crossed by some dykes of white gneiss-granite. The same rocks continue as far as Besham Qila, near the junction of the Khan Khwar river with the Indus river. Along the left bank of the Indus, between Besham Qila and Patan, an ultramafic complex crops out which, in the sketch-map accompanying my 1974 paper, is included in the Middle Indus Noritic Group (2). My present opinion, instead, is that the complex does not belong to this group, but is an independent rock-body, like that of Shangla pass, inserted between the Lower Swat Buner Schistose Group of Martin, Siddiqui and King (1962) and the Noritic Group. The ultra-mafic complex is interrupted upstream by a fault (Patan fault) which crosses the Indus river and is responsible for the earthquake of 28th December, 1974 (3).

The petrology of the basic and intermediate rocks between the Indus and the Swat rivers has been illustrated by N. R. Martin *et al.* (1962), F. A. Shams (1972), and M. Q. Jan and D. R. C. Kempe (1973), and others.

According to these authors the above mentioned ultramafic body between Patan and Jijal (Jijal Ultramafics of Jan and Kempe) is made up of hornblende gneiss grading to pyroxenites with local peridotites and dunites. On the northern side of the Patan fault a belt of epidote amphibolites outcrops and these spread largely westwards in the upper Swat valley. The amphibolites are followed north by other parallel belts oriented SW–NE and made up of noritic gabbros (Upper Swat Hornblendic Group = Middle Indus Noritic Group), and north-west of Utror Volcanics and the Gabral Plutonic Group.

The above-mentioned belts continue westwards in the Panjikora valley and Dir area as far as the Laworay pass, where similar rock systems are present and most likely much more to south-west as far as the eastern Afghanistan. A similar basic and intermediate complex is to be found north of

(2) A correction is to be made in the graphic scale of the map, substituting 10 and 20 km for 2 and 4 km.

(3) The magnitude was 6.2 and the focal depth shallow. The number of victims was estimated as 5300 and the injured 17.000. The hamlet of Patan was completely destroyed.

Asmar in the tectonic wedge between the Kunar fault (SW continuation of Drosh fault) and the Mokur fault which seems to be the south-western extension of the Patan fault (Desio, 1977).

The Patan fault, which can be followed from the Swat river as far as the Middle Indus, also according to N. R. Martin, S. F. A. Siddiqui and B. H. King (1962), and R. G. Davies (1965), is to be interpreted as a thrust-fault, whilst Jan and Kempe (1973) do not seem to be of the same opinion. As I have said, the fault divides the Upper Swat Hornblendic Group from the underthrusted Lower Swat Buner Schistose Group; the first was referred to the Cretaceous-Eocene [4] and the second, according to Martin *et al.* (1962), to the Paleozoic, but this is not substantiated by sound evidence.

East of the Indus, as far as the Babusar road, our geological knowledge is scanty. We know something about the Karakorum Highway (Jan, 1970 and Desio, 1974) and the Thak valley (Shams, 1975), but a large area is still black on the maps.

As we know (Desio, 1974), upstream from Patan the river cross a large complex of amphibole (hornblende) orthogneiss and amphibolites, and farther on a rock body of amphibole quartz diorite and diorite, separated from the preceding complex by a narrow belt of laminated prasinitic schist ("Shatial Schists") [5] crops out. Upstream from the junction of the Kandia river the Noritic Group spreads out toward the junction of the Gilgit and Indus rivers and farther on along the northern slope of the Gilgit valley as far as the lower Hunza valley.

A similar sequence was described by Shams (1975) in the Thak valley as far as the Babusar pass. The "amphibole (hornblende) orthogneiss and amphibolite complex" is to be correlated with "hornblende-epidote gneisses and amphibolites" of the northern slope of the Babusar, where the complex, which has a similar mineralogical composition, is interrupted by an "apparently tectonic break". Desio's Shatial Schists in the Middle Indus valley represent the "chlorite and epidote schists" of Shams in the Thak valley.

The amphibolite belt of the Middle Swat continues an ENE direction and after having crossed the Indus river around Kamila bridge (Jalkot), continues to the east as far as the western slope of the Nanga Parbat massif. West of the Indus valley the amphibole orthogneiss seems to be in contact with, or perhaps to grade into the noritic gabbro of the Lower Swat.

I want to emphasize here the presence of an "apparently tectonic break" announced by Shams on the northern slope of the Babusar pass which separate the hornblende-epidote gneiss and amphibolite complex, to the north, from the Precambrian Salkhala formation, to the south. This is made up of

(4) The K/Ar age of a pegmatite hornblende sample has been determined as 67 m.y. (Jan and Kempe, 1973), that is Paleocene. These authors located this group at the lowest level of the local stratigraphy and it was therefore supposed to be very old.

(5) Probably the "Shatial Schists" are to be correlated with the "Kandia Schists" of Jan (1970).

graphitic schists, amphibolites, calcschists, pelitic schists, and quartzites with sporadic quartz-feldspathic gneiss. I think that this tectonic break is to be interpreted as a thrust-fault which is to be linked with the Patan fault. This tectonic connection is emphasized also by the ERTS imageries (Ebblin, 1976).

I have tried here to outline very briefly some peculiar geological features of this area, on account of the presence of the glaucophane schists which are endowed with particular petrotectonic meaning. According to recent interpretations (M. C. Blacke, W. P. Irwin and R. G. Coleman (1969), J. F. Dewey and J. M. Bird (1970), W. G. Ernst (1975, etc.), the glaucophane schists belong to those peculiar metamorphic facies, known as *blueschist facies*, which occur, together with ultramafic rocks, only in those narrow tectonic belts which mark subduction zones. The presence of blueschists around the Shangla pass may be evidence of this kind of phenomenon.

Other elements support this assumption.

The Patan fault, that can be followed from the Swat river to the Babusar pass, is to be linked eastwards with the " Nanga Parbat western tectonic line " which runs along the western slope of the massif (Misch, 1949; Desio, 1964).

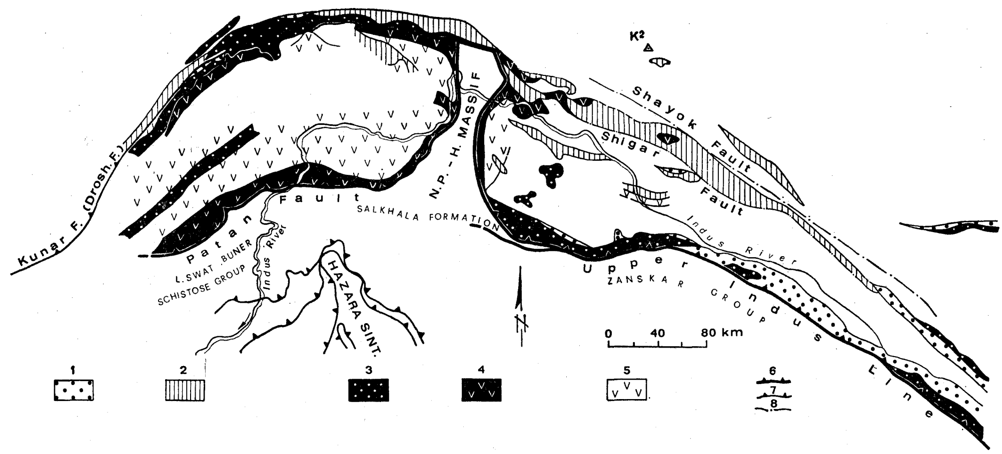

Fig. 2. – The ophiolitic belts and the upper Indus line with its western section. 1) Sedimentary Flysch; 2) Metamorphic Flysch = Shigar Gr., Chalt Gr.; 3) Ophiolites = basic lavas and tufa; 4) Metamorphic ophiolites (mostly amphibolites); 5) Intermediate and basic plutonics (mostly Noritic group); 6) Assumed subduction thrust-fault; 7) Overthrust-fault; 8) Fault.

The " Nanga Parbat western tectonic line " is the homologue of the " Nanga Parbat eastern tectonic line " (fig. 2) and represents the western stretch of the " Upper Indus suture line " of Gansser (1964). These western and eastern Nanga Parbat tectonic lines seem to be connected one to another at the northern extremity of the Haramosh massif and Gansser and others have adopted this extrapolation on account of the presence of an ophiolite belt also to the west of Nanga Parbat as pointed out by Wadia and Misch.

Actually there is no evidence as to this connection since the large ice blanket of the Upper Chogo Lungma glacier hides the rocks in this area (see Desio's Geological Map, 1964). In any case, if we assume such a connection, we realize the continuity of the Indus suture line with the Patan fault which is supported also by other geological assessments.

Within both areas, west and east of Nanga Parbat, the rock complexes straddling the tectonic line are in fact, comparable. On one side (south) there are Precambrian or Paleozoic sedimentary or metasedimentary formations, like the Zanskar sequences, or the Precambrian Salkhala and the Paleozoic Lower Swat Buner Schistose Group. On the other side (north) Cretaceous-Eocene formations to the east of Nanga Parbat like the Upper Indus Flysch with ophiolites and basic intrusives; to the west of Nanga Parbat, the metamorphic facies of the ophiolites with basic intrusives like the Middle Indus Noritic Group and the equivalent Upper Swat Hornblendic Group.

In conclusion, Gansser's interpretation of the Indus suture line as the track of a subduction zone, is applicable also to the west of the Nanga Parbat-Haramosh massif, where a new element in its favour is the discovery of blueschists around the Shangla pass (6).

It is worthwhile noticing the location of this lithotype to the south of the fault, on the underthrusted block, and very close to the northern border, i.e. the Patan thrust-fault line (fig. 3).

The great majority of recent authors (see review in W. G. Ernst, 1975) assume that the only tectonic-metamorphic environment required for the formation of blueschists is to be found within the geosutures developed on the edges of interacting lithospheric plates where subduction is active and the rocks are submitted to low temperature combined with high pressure metamorphism. Moreover, according to M. C. Black Jr. and others (1969), the blueschist facies is located in the upper part of the lower plate, along the sole of the thrust-fault. Common to the same facies is the association of blueschists and ophiolites, which, according to Coleman (1973), are invariably older than the blueschists and their development is as long and narrow belts parallel to the tectonic trend. But blueschists (and eclogites) are also present as olistoliths in the " melange " zones, particularly in the collision mountain belts. Someting is to be added about the possible age of the Shangla pass blueschists.

According to Jan and Kempe (1973) the ultramafic masses of the area examined with which the blueschist are associated, seem to be " perhaps early Tertiary ".

Similar rock sequences occur in the area to the east of the Nanga Parbat massif. The closer and better known of them are those of Dras and Kargil.

According to the majority of authors (see summary in Oldham, 1959, and Gupta and Kumar, 1975) the age of the Dras Volcanics is confined between

(6) A. K. Crawford (1974) expressed a different opinion on this subject, but a preliminary report such as this one is not the place for discussing it.

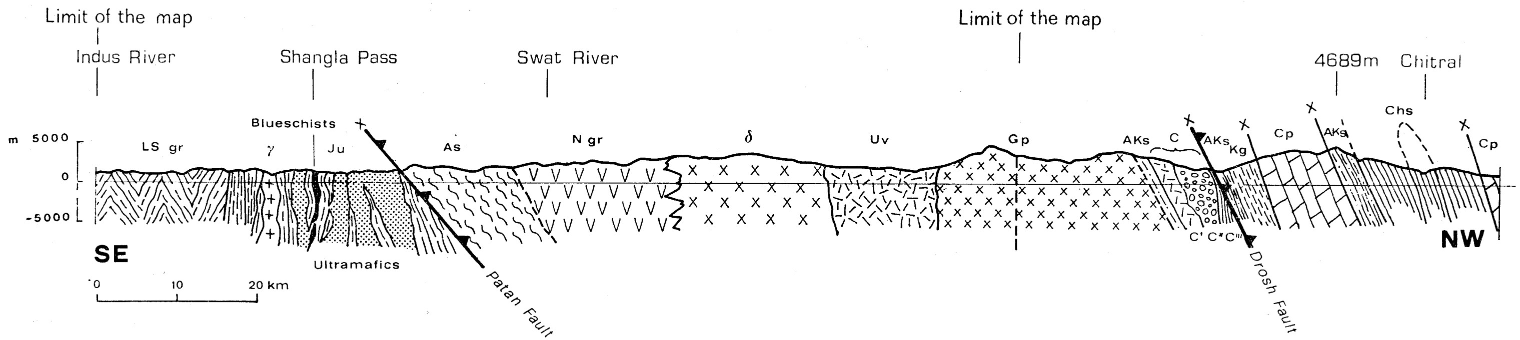

Fig. 3. – Geological cross-section from the Middle Indus River to the Chitral Valley. AKs = Ashreth-Koghozi Schists; C = Cretaceous section: C′ = Mirkani Quartz Porphyrite: C″ = Dundi Gal Volcanic agglomerate; C‴ = *Orbitolina* limestone; Kg = Kesu Gneiss; Cp = Cipollino; Chs = Chitral Slates; Gp = Gabral Plutonics (Gabbrodiorites); Uv = Utror Volcanics; δ = Diorites; Ngr = Noritic group; As = Amphibolites; Ju = Jijal ultramafics: LSgr = Lower Swat Schistose group; γ = Leucogranite; x = Fault.

the Early Cretaceous and the end of the Lower Eocene. The Dras Volcanics (ophiolites) are associated with a Flysch sequence, often rich in fossil content. Another occurrence of a similar sequence is exposed at Burzil pass, between Dras and the Nanga Parbat massif, where D. N. Wadia (1937) found a Cretaceous fossiliferous bed included in the Dras Volcanics. According to Wadia, the age of the Dras Volcanics is to be referred to the Early and Middle Cretaceous, but the fossils belong to the Aptian.

The farther extension of the same ophiolitic belt along the eastern slope of Nanga Parbat is described by P. Misch (1949), who also demostrates the gradual passage from the sedimentary and volcanic sequences to the metamorphic ones in both sides of the massif.

In this way we can approximatively date the blueschists of the Shangla pass in the Early Tertiary (Paleocene?).

As to the area involved in the discussed geotectonic structure to the west of Nanga Parbat, I postulate the existence of a wider belt than previously supposed. The isolated and small occurrences of Cretaceous beds with volcanics, like those of Yasin, Chumarkhan, Nal (Drosh), Kring (Chitral), and Dundi Gal near Drosh (Desio 1959), may be interpreted as tectonic splinters inserted within the bundle of faults of the old trench structures produced by the subduction process.

West of the Nanga Parbat-Haramosh massif the belt represents the upper Indus ophiolite-flysch " melange " parallel, like this one, to the tectonic trend and with the same geotectonic meaning, but more complex and wider than to the east of the massif.

There are many problems involved in these hypotheses which are in need of clarification; but the task of the present paper is much more modest, that is to evidence the consequence of the discovery of blueschists at the Shangla pass.

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