Atti Accademia Nazionale dei Lincei

Classe Scienze Fisiche Matematiche Naturali

Rendiconti

Claudio Ebblin

Structural Geology of the Thalle Area, Baltistan, Karakorum, Central Asia. Nota I

Atti della Accademia Nazionale dei Lincei. Classe di Scienze Fisiche, Matematiche e Naturali. Rendiconti, Serie 8, Vol. **60** (1976), n.5, p. 663–671.

Accademia Nazionale dei Lincei

<http://www.bdim.eu/item?id=RLINA_1976_8_60_5_663_0>

Atti della Accademia Nazionale dei Lincei. Classe di Scienze Fisiche, Matematiche e Naturali. Rendiconti, Accademia Nazionale dei Lincei, 1976.

Geologia. — *Structural Geology of the Thalle Area, Baltistan, Karakorum, Central Asia.* Nota I di CLAUDIO EBBLIN, presentata (*) dal Socio A. DESIO.

RIASSUNTO. — Le osservazioni delle strutture geologiche macroscopiche nelle valli di Bauma–Harel, di Yangsa e di Thalle nelle vicinanze di Skardu nel Pakistan settentrionale hanno permesso di localizzare le tracce dei piani assiali delle maggiori pieghe. Le strutture rilevate sono state interpretate come il prodotto della sovrapposizione di due stadi di deformazione. Lo stadio più antico durante il quale si è formata la scistosità è caratterizzato da un raccorciamento principale finito suborizzontale in direzione NE–SW ed è stato messo in relazione al formarsi del Batolite assiale del Karakorum. Il secondo stadio, più recente, che ha causato un raccorciamento principale finito subverticale è legato al piegamento della scistosità, e potrebbe essere stato causato da un eccesso di peso ai livelli sovrastanti dovuto forse ad un accavallamento di rocce del basamento su quelle della copertura. Posteriore ad entrambi le fasi deformazionali è considerata l'intrusione di rocce gabbrodioritiche avvenuta lungo i piani di scistosità.

1. INTRODUCTION

The aim of this work was to introduce and apply modern techniques of structural geological mapping in the Karakorum in order to clarify the tectonic relationships between certain geological formations.

The area in which the survey was carried out is in the vicinity of the town of Skardu, northeastern Pakistan (fig. 1).

Previous petrographic work had been carried out Northwest of this area by Zanettin (1964) and East of it by Giobbi Mancini (Desio and Giobbi Mancini, 1974) and geological work by Desio (1964; Desio and Giobbi Mancini, 1974). In the Shigar Valley (Zanettin, 1964) the lithological section is made of a metamorphosed basic volcano sedimentary sequence thought to be of Cretaceous age overlain by a slightly metamorphosed sedimentary sequence probably belonging to the Eocene. Many of the metamorphic rocks display traces of an older metamorphic assemblage at the expense of which the main schistosity seems to have formed; furthermore, quite often the schistosity appears to be deformed by a crenulation cleavage with zones of fresh, randomly oriented crystals. It is not clear what the relationship between these different deformational stages and the igneous activity might be, however the metamorphic grade of the rocks seems to be strongly dependent on such igneous activity (Zanettin, 1964) and one is thus tempted to conclude that the schistosity formed during this activity.

Giobbi Mancini (Desio and Giobbi Mancini, 1974) examined samples of rocks collected along the Hushe Valley and Masherbrum Valley. Most

(*) Nella seduta dell'8 maggio 1976.

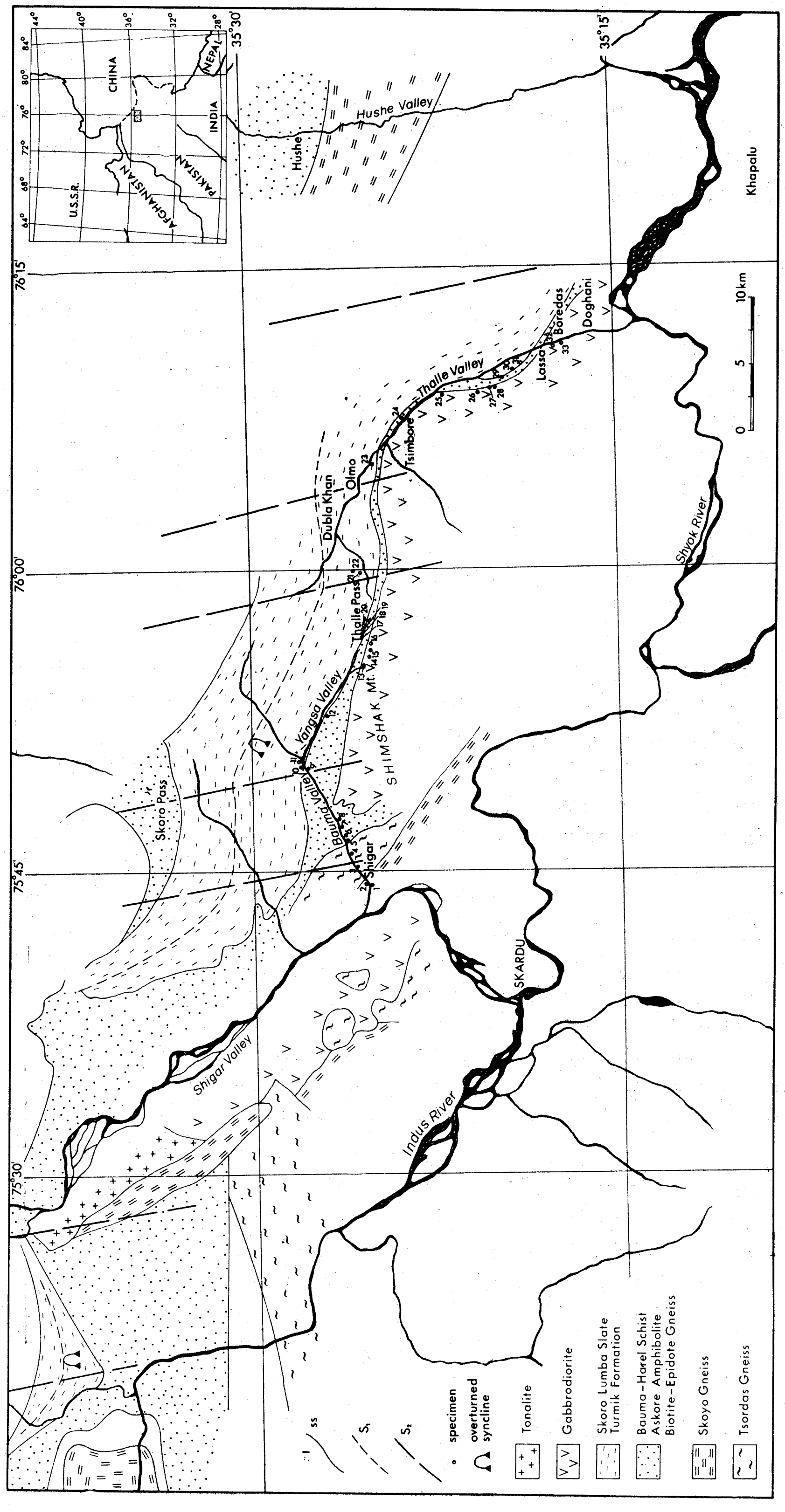

Fig. 1. – Map of the Thalle Area and surrounding territory.

of these specimens display high-grade metamorphic assemblages which reveal four distinguishable metamorphic stages. The oldest stage was believed to be connected with the formation of the schistosity in the pelitic rocks, the following one which was a static one was related to the intrusion of a granitic mass which caused widespread magmatization and anatexis, the third one caused the « rotation » of some of the crystals and the last phase, which was again a static one, was connected with the intrusion of the Baltoro Granite which occurred in Miocene time.

Thus it seems that both in the Shigar Valley and in the Hushe and Masherbrum valleys the formation of the schistosity was perhaps connected with synkinematic granitic intrusion and certainly occurred before the emplacement of the Baltoro Granite.

2. DESCRIPTION OF GEOLOGY

2.1. *The lithostratigraphical sequence.*

The sequence of rocks exposed along the Bauma-Harel Valley from the village of Shigar to the intersection with the Yangsa Valley can be divided into two distinguishable lithological units.

The first unit starts along the lower part of the profile with medium-grained quartz-biotite-epidote gneisses (ET 1 [1], ET 2) different from the following rocks owing to their larger grain size. Further on there are quite fine-grained biotite amphibolites (ET 5) intercalated with some belts of calcareous schists (ET 4) and intruded by retrograde, metamorphosed quartz-diorites (ET 3) which in places show a strong preferential orientation of the amphiboles. These rocks often overgo into quartz-amphibole schists (ET 7) and biotite schists (ET 6) which about half way between the village of Shigar and the intersection with the Yangsa Valley turn into chlorite-epidote schists still intruded by coarser-grained metamorphosed diorites.

Structurally overlying the greenschists about 300 metres before the intersection with the Yangsa Valley one finds the second unit made of a slightly metamorphosed sedimentary sequence composed of black and white slates with some layers of fine-grained conglomerate (ET 9, ET 11).

Proceeding along the Yangsa Valley one finds that the slates show no appreciable compositional variation along the strike. However about 4 km up the valley the greenschists of the lower unit are seen to outcrop on the left bank and from here on the whole southern slope displays exposures of suboophitic amphibolites (ET 12, ET 14) and porphyritic gabbrodiorites (ET 13). Thus the valley marks the contact between the third lithological unit which is a basic igneous complex and the lower volcano-sedimentary unit on one side and the sedimentary sequence on the other.

(1) The description of specimens is given in the Appendix.

High up, almost at Thalle Pass, one finds more or less altered quartziferous diorites (ET 15, ET 16) to the South, making up the peaks of Shimshak, and fine-grained red arenaceous rocks (ET 17, ET 19) and gray phyllites (ET 18) often containing larger quartz clasts to the North. A conglomerate with quartzite and limestone pebbles in a chloritic matrix (ET 20) is also observed at the height of the pass. Thus the belt of slates, here possibly somewhat thinner, ought to occupy the bottom of the valley and the arenaceous rocks ought to overlie it.

On the other side of Thalle Pass the northern slope of the valley is still entirely made of red arenaceous rocks which may contain variable amounts of amphibole and epidote (ET 21) or of sericite (ET 22) and are undoubtedly the continuation of the arenaceous rocks observed on the western side of the pass.

The underlying belt of slates outcrops again near the village of Olmo with large exposures of rusty black phyllites and of quartziferous phyllites (ET 23). These rocks continue to the mouth of the Tsimbore Valley, where the dioritic rocks reappear under a belt of biotite-epidote gneisses. The exposure of gabbro diorite continue almost to the village of Baltoro. Along with them one finds examples of metamorphosed dolerites (ET 26), amphibolites (ET 25) and of biotite-muscovite gneisses (ET 27).

For about 300 metres beyond the village of Baltoro there are exposures of biotite-epidote gneiss (ET 28, ET 29) and from there on one finds an exposure of greenschists, some quartz-chlorite phyllites (ET 30), and more diorites, black schists and extensive fine-grained amphibolites which continue almost to the village of Tassa. There at the mouth of the right tributary valley quartz-amphibole phyllites (ET 31) followed by biotitic amphibolites are exposed.

About half way between the villages of Tassa and Boredas the rocks are biotite-amphibole gneisses (ET 32) followed by fresh gabbro diorites (ET 33) which continue all the way to the mouth of the Thalle Valley.

The rocks observed along the Bauma–Harel, Yangsa and Thalle valleys can be grouped into the three following lithological units:

1) an *igneous complex* composed of gabbrodiorites (ET 33), occasionally porphyritic (ET 13), which are sometimes quartziferous (ET 15), and at times grade into quartz-diorites (ET 3). Some of them are recrystallized (ET 16) and almost always altered (ET 26);

2) a *volcano-sedimentary sequence* constituted by chlorite-epidote schists (ET 12) or chlorite schists (ET 14) sometimes containing remarkable amounts of quartz (ET 30). Higher-grade counterparts like biotite-epidote gneisses (ET 28, ET 29) and quartz-biotite-epidote gneisses (ET 1, ET 2) are also abundant. These rocks are often associated with biotite gneisses (ET 4, ET 6), sometimes muscovite-bearing (ET 27), with biotite-amphibole gneisses (ET 5, ET 32) or quartz-amphibole phyllites (ET 7, ET 31) and also with amphibolites (ET 25). In spite of the clear metamorphism displayed by

most of these rocks their suboophitic-texture is quite apparent thus suggesting their volcano-sedimentary origin;

3) a *sedimentary sequence* characterized by argillaceous rocks in its lowest part and by quite quartz-rich rocks (ET 8, ET 21) higher up in the section. Occasionally these are argillaceous (ET 18, ET 22, ET 23) and often turn into conglomeratic counterparts (ET 17, ET 19) or even into true conglomerates (ET 9, ET 11, ET 20).

The axial traces of three major folds of late generation seem to cross the investigated area. One of these traces stretches through the intersection between the Yangsa Valley and the Bauma-Harel Valley; another one should be found between Thalle Pass and the village of Doubla Khan and the third one near the village of Olmo.

The existence of some more axial traces of major folds of the same generation can be extrapolated tentatively to the surrounding area (fig. 1).

The axial surfaces above fold the axial surfaces of earlier subsoclinal folds. Indeed a major early fold was reported from Ganto Pass (Zanettin, 1964) and another one is believed to exist just South of it. Furthermore it is suggested that the exposures of the sedimentary sequence also mark the axial trace of such an additional fold.

2.2. *The rocks and the structures of the Bauma–Harel valley.*

On the outskirts of the village of Shigar, at the mouth of the Bauma-Harel valley, there are the first spectacular exposures of a light-gray quartz-biotite-epidote gneiss. This rock shows a weak compositional banding marked by a few centimetre-long biotite-rich lenses which dip some 20° to the SW and are crenulated to form a lineation stretching to the ESE. Further up on the left bank of the stream the crenulation is more intense and asymmetric folds of a couple of decimetres of wave length appear related to it. The axial surface of these folds is sub-horizontal and cuts their steeper enveloping surfaces showing that possible major folds of the same generation ought to be recumbent and ought to close to the SW further down in the section and to the NE higher up.

Proceeding to the NE the compositional banding becomes steeper suggesting that one is getting nearer to the nose of a major fold. A leucocratic layer, parallel to the compositional banding also shows a train of asymmetric folds of concentric type that overgo into a crenulation in the more basic layers (fig. 2). Here both the compositional banding and the axial surfaces dip to the N, the former more steeply than the latter showing that this exposure must lie on the other limb of a major fold.

All folds described to this point proved to bend the schistosity of the rock. However the next exposure displays a fold in the compositional banding that has its axial surface parallel to the schistosity. Obviously such a fold was formed during an older deformational stage as also suggested by its similar shape. Thus it is seen that a deformational event prior to the one that gave birth to the crenulation had also produced folding.

Further up along the valley the gneisses are marked by more epidote-rich layers. Relationships between the compositional banding and the crenulation cleavage show that the nose of the next major crenulation fold lies further to the NE. About 100 m up from the mouth of the Bauma-Harel Valley a rather spectacular fold (fig. 3) shows that the structural analysis carried out to this point is correct. Some 20 m further on the rocks display a more definite banding steeper than its cross-cutting schistosity suggesting that this is the overturned limb of a major fold of older generation. Crenulation folds disappear and the rocks become progressively richer in amphiboles often concentrated in spots. Occasionally 5 cm-large inclusions of epidote are also seen in rocks which seem to be recrystallized quartz-diorites.

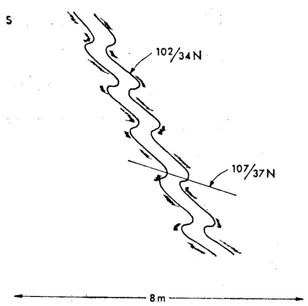

Fig. 2. – Sketch of a folded leucocratic layer in a quartz-biotite-epidote gneiss.

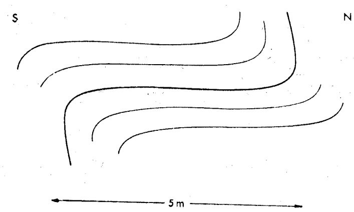

Fig. 3. – Rather large fold in agreement with the structural reconstruction.

Then, after the confluence of a small left tributary valley, the presence of quartz is detected in the rocks. Here the compositional banding is very planar and dips steeply to the North. Bands of calc-schist alternated with ones of a very dark biotitic amphibolite and with biotite schist outcrop all the way to the confluence of the third left tributary valley. The orientation of the compositional banding is quite constant and its dips vary from 60° to 90° to the N.

Although the greenschists observed after the location above display an alignment of minerals subparallel to the compositional banding in the layered rocks, such schistosity is far less planar than the compositional banding in the rocks further downstream. At times 1–2 cm-long pebbles are found in the schists; however occasionally they can be as long as 10–15 cm. The latter are generally rich in epidote and exhibit an elongation 4 times larger in a direction parallel to the schistosity than perpendicularly to it. Here and there massive greenstones also occur. Apart from the greenstones, NE of the confluence with the next tributary valley, occurrences of red extremely fine-grained, metamorphosed quartz rocks are seen in a bulk of greenschists.

About 250 m before the confluence with the Yangsa Valley the greenschists are intertangled with light-brown schists. From here on the rocks seem to make up a less metamorphosed sedimentary sequence. Up to the mouth of the Yangsa Valley one finds an alternation of black and white slates intercalated with some green ones. Right across from the mouth of the Yangsa Valley, on the right bank, among these rocks a conglomerate with calcareous pebbles is also found. Here the cleavage of the rocks dips to the NE more steeply than the compositional banding suggesting that this is the normal limb of a major overturned fold of older generation.

2.3. *The Yangsa Valley.*

This valley stretches in a southeasterly direction, following the strike of the compositional banding and the cleavage of the rocks. Thus the exploration of this valley does not provide much information about the megastructures of the area.

The exposures of slates continue right up to the foot of the Shimshak where after some fine-grained amphibolites there is an area of porphyritic gabbrodiorite. Occasionally belts of quartz-rich rocks also occur. A variety of rocks of this type and of more or less quartziferous diorites make up the whole of the northern slope of the Shimshak.

The sedimentary rocks are found again about 500 m before the Thalle Pass on the right side of the Valley. Here a red fine-grained, quartz-rich arenaceous rock is seen to underlie a gray phyllite which exhibits small kinks, the axial surface of which is marked by a fracture cleavage. However the orientation of such cleavage is far from being constant; on the contrary the cleavage seems to occur along a set of conjugate shears.

Further on, at about 200 m from the pass, the red arenaceous rock outcrops again, this time together with a conglomerate which can be followed all the way to the pass. In a green, schistose matrix the quartzite and limestone pebbles are elongated in the plane of the schistosity and the ratio of their dimensions perpendicular and parallel to the schistosity is about 1 : 20. On the schistosity, dipping moderately to the NE, a lineation bearing North is also apparent. On the other side of the pass exposures of greenschist display a cleavage dipping to the NE more steeply than the compositional banding. The fact that the spatial relationship between the cleavage and the compositional banding changes so often suggests that the major folds which are likely to exist are rather tight. North of here from a distance the rocks appear to belong to the sedimentary sequence, but to the South mostly greenstones and greenschists seem to occur.

The left side of the valley shows a large number of exposures of quartzite some of it containing variable amounts of amphibole, of epidote or of calcite abundantly intercalated with layers red quartz-feldspar gneiss. These outcrops display a remarkable number of structural details. A young cleavage generally dipping shallowly to the E bends the older one, the orientation of which dips very steeply to the North. On this older cleavage a mineral lineation bears West.

In spite of the quite prominent late cleavage, the earlier one, parallel to the compositional banding, is clearly detectable. Futhermore remarkable mirror surfaces dipping fairly steeply to the SE are also seen and on these the slickenside marks bear SSW.

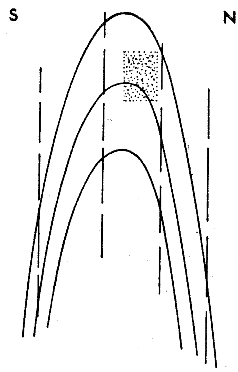

Fig. 4. – Reconstruction of a probable early fold ENE of Thalle Pass. Full line: compositional banding, dotted line: main cleavage, stippled area: exposed relationship.

At the very top of the ridge the orientation of the compositional banding departs from that of the older cleavage. Although this cleavage is subvertical in an E–W direction the banding dips moderately to the West and the youngest cleavage to the East. Hence this outcrop probably marks the nose of a fold of early generation (fig. 4).

2.4. *Thalle Valley.*

In the vicinity of the village of Olmo a rusty black phyllite displays a schistosity which dips steeply to the South and cross-cuts an older one subvertical in an ENE direction. The latest cleavage is still present.

Some more exposures show that the remnants of the oldest schistosity are always cross-cut by a steeper main schistosity. This relationship would suggest that even here the axial zone of a fold of early generation might be found. If this is so, between Olmo and the Thalle Pass the hinge of a major EW-trending early antiform ought to be found.

Provided that the latest deformational stage has not distorted the relationship between the earlier structures too much one finds that the smaller angle between the two schistosities present in the quartz-rich slates exposed near Bukma hints at the likeliness that here more of a limb position of the above fold might be exposed.

At the mouth of the Tsimbore Valley the relationship between the older schistosities is still very clear. However measurements obtained from a gray quartzite and from a greenschist are somewhat different; indeed, in spite of the fairly constant orientation of the earlier cleavage the main schistosity is much steeper in the former rock than in the latter one. Hence this is likely to be a case of cleavage refraction. From the angle between the schistosities of different generation it is obvious that this outcrop marks again the axial zone of a major fold of early generation; however it is difficult to say whether this would be the same antiform seen North of Olmo and taken around by the later deformation or rather the corresponding synform South of it.

From here to an exposure just North of Tari all rocks appear to belong to a basic intrusive complex and although many of them show a good degree of fracturing, on the whole they appear hardly deformed. Occasionally fine-grained banded biotite-epidote gneisses are also seen with their planar features generally dipping steeply to the West. However a second set of cleavages tend to exhibit a moderate northeasterly dip.

In the area around Tari there are many exposures of very fine-grained amphibolites and of folded metamorphosed dacites which are quite well-preserved. In these rocks a schistosity is often seen to cross-cut a compositional banding and in different outcrops the relationship between these structural elements appears very similar. Indeed, in spite of the diversity in the orientation of the banding and that of the cleavage in each locality the relationship between the two suggests that even this could be the axial zone of a major fold and that the nose might have been merely rotated by the later deformation.

South of Tassa the metamorphic rocks turn into igneous ones and structural details are missing. The rocks are mainly gabbrodiorites and can be related to the ones found between the Tsimbore Valley and Tari and to those of the Shimshak. However in the vicinity of Tassa several huge boulders of a granitic rock were also observed. The outcrops of the basic rocks continue all the way to the mouth of the Thalle Valley.

REFERENCES

DESIO A. (1964) – *Geological Tentative Map of the Western Karakorum*, Scale 1 : 500,000; « Ist. Geologia, Università di Milano », Milano.

DESIO A. and GIOBBI MANCINI E. (1974) – *On the Geology of the Southern Slope of the Masherbrum Peak and the Upper Hushe Valley (Karakorum, Central Asia)*, « Acc. Naz. Lincei, Mem., Cl. Sc. fis., mat. e nat. », ser. 8, *12*, sez. 2, 79–100.

DESIO A., TONGIORGI E. and FERRARA G. (1964) – *On the Geological Age of Some Granites of the Karakorum, Hindu Kush and Badakhshan (Central Asia)*, 22nd Intern. Geol. Congress, India, part 11, section 11, 479–496.

DESIO A. and ZANETTIN B. (1956) – *Sulla Costituzione Geologica del Karakorum Occidentale (Himalaya)*, 20th Intern. Geol. Congr., Mexico, Section 15.

FLINN D. (1961) – *On Deformation at Thrust-planes in Shetland and the Jotunheim Area of Norway*, « Geol. Mag. », *98*, 245–56.

ZANETTIN B. (1964) – *Geology and Petrology of Haramosh-Mango Gusor area*, In: Scient. Reports of Ital. Expedition to the Karakorum and Hindu Kush, A. Desio Leader, III, vol. 1, F. J. Brill, Leiden.