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Reconnaissance geology of the Hushe and Saltoro-Kondus river valleys, Karakorum Mountains, Kashmir, Pakistan

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Geologia. — *Reconnaissance geology of the Hushe and Saltoro-Kondus river valleys, Karakorum Mountains, Kashmir, Pakistan.* Nota di MICHAEL E. BROOKFIELD (*), presentata (**) dal Socio A. DESIO.

RIASSUNTO. — L'autore illustra brevemente i risultati di una ricognizione geologica effettuata nelle valli Hushe, Kondus e Saltoro. Egli distingue nell'area esaminata 3 principali unità tettoniche: *a*) Batolite Ladak–Deosai, *b*) zona di sutura (melange) dello Shyok, *c*) Batolite assiale del Karakorum.

Il primo consiste di una grande intrusione granodioritica che verso sud attraversa un complesso gneissico a sua volta attraversato da dicchi di microdiorite.

Il passaggio verso la zona di melange dello Shyok è graduale. Questa ultima inizia con un tipico melange ofiolitico che passa ad un flysch sempre più metamorfico verso nord il quale culmina con scisti e gneiss biotitico–plagioclasici intercalati con banchi di marmo e di melange serpentinico.

La zona del batolite assiale del Karakorum è rappresentata per lo più da una sequenza relativamente uniforme di gneiss occhiadini biotitici o biotitico–plagioclasici, derivati da dioriti quarzifere, o da dioriti quarzifere, come nell'area del Kondus e del Saltoro.

Queste zone portano i segni di varie fasi dinamiche in buona parte specifiche di ciascuna di esse.

INTRODUCTION

The area studied lies around 35° 30′ N, 76° 30′ E on the southern flank of the Karakorum Mountains.

The Hushe and Saltoro–Kondus rivers are tributaries of the Shyok. The Hushe drains the southern slopes of Masherbrum peak: the Saltoro–Kondus drains the Saltoro Group of mountains.

Desio and Giobbi (1974) compiled a paper on the Hushe valley based on early reconnaissance studies and collections of rocks made by D. Alessandri during Barbuscio's 1969 "Abruzzi expedition" to K^6 peak. Some observations have hitherto been made in the Saltoro–Kondus area by C. Calciati (1911), A. Roccati (1915), P. Aloisi (1933), G. Dainelli (1934), A. Desio (1964, 1976).

The purpose of this study was to primarily obtain samples for radiometric dating and make some observations of an area previously blank on the map. It was also hoped to confirm the presence of fossiliferous Ordovician on the southern slopes of Masherbrum. The results are shown on a map (Fig. 1) and cross section (Fig. 2).

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(**) Nella seduta dell'8 novembre 1980.

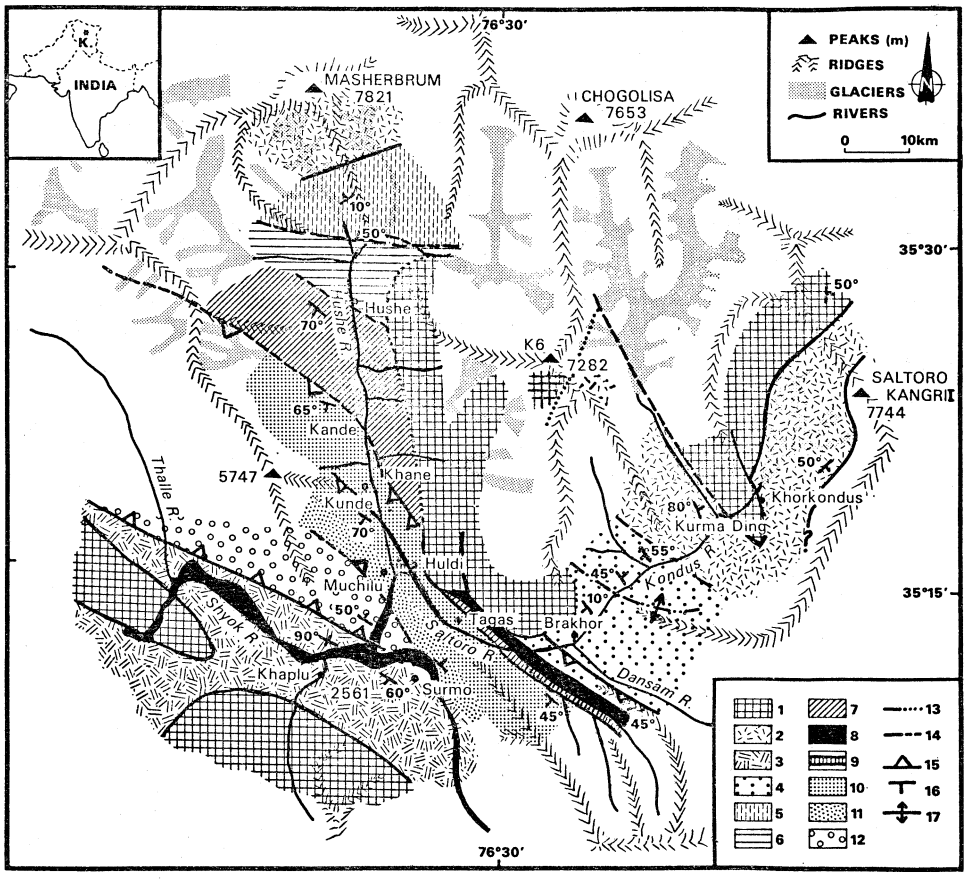

Fig. 1. – Reconnaissance geological map of the Hushe and Saltoro–Kondus river valleys.

LEGEND:

1 – Granodiorite, quartz-diorite, tonalite, etc.
2 – Metaigneous rocks, predominantly dioritic gneisses and augen gneiss.
3 – Metasedimentary and metaigneous gneisses and schists marginal to the Ladakh-Deosai batholiths.
4 – Biotite and hornblende-garnet-biotite gneiss.
5 – Metasedimentary quartz-feldspathic and pelitic gneisses, some marble.
6 – Biotite-epidote gneiss.
7 – Biotite-plagioclase augen gneiss, derived from quartz-diorite.
8 – Ultramafics: amphibolites, pyroxenites, etc.
9 – Dolomite marble.
10 – Fine-grained interlayered biotite-plagioclase gneiss and schist (metamorphosed 'flysch').
11 – Ophiolitic melange: serpentinite breccia, basalt, marble, chert, etc.
12 – Basalt and greenschist.
13 – Contacts: defined, assumed.
14 – Faults: defined, assumed.
15 – Thrust faults: tooth on upper plate.
16 – Dip, in degrees, of bedding, foliation.
17 – Axis of anticline.

The area can be divided up into three main tectonic units, from south to north, these are:

1. The Ladakh–Deosai batholith complex.
2. The Shyok suture melange zone.
3. The Karakorum axial batholith complex.

1. *The Ladakh–Deosai batholith complex.*

This outcrops south of the Shyok river at Khaplu and extends north of the river on the western side of the Hushe valley. It consists of a large granodioritic intrusion on the south intruding vertical quartz-feldspathic mioaceous gneisses, pelitic and dioritic gneisses; themselves cut by gently dipping microdioritic dykes. Towards the Shyok river, the rocks are badly crushed. The contact with the Shyok melange zone is gradual. At Surmo a shattered mylonitized melange of amphibolite, quartzite, mica-gneiss, diorite, quartz-diorite, together with large masses of greenschist, apparently mark the start of the melange.

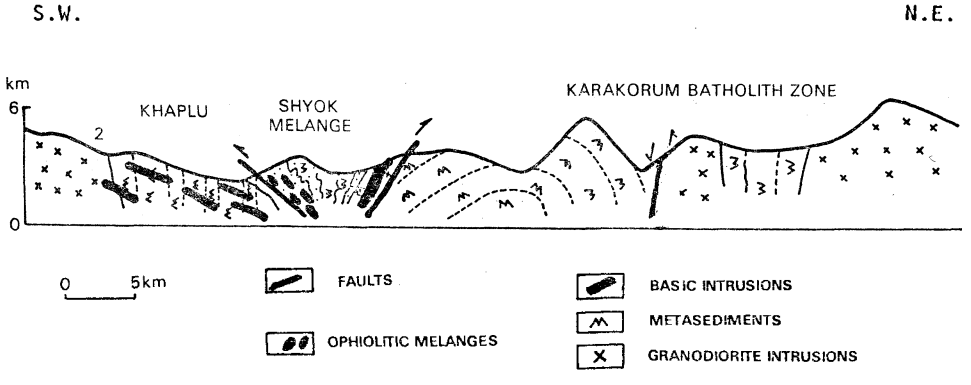

Fig. 2. – Cross-section from Khaplu to Saltoro Kangri I.

2. *The Shyok suture melange zone.*

On the north side of the Shyok river, along the western side of the Hushe valley, a thick zone of northward dipping greenschists and amphibolites mixed with and intruded by, micro-diorite, are succeeded by a thick series of banded quartzo-feldspathic schists gneisses. In these the dips gradually change to the south and isoclinal folds, with axial planes dipping steeply south-westwards are developed. These pass northwards into quarzo-feldspathic and muscovite gneisses with dioritic gneisses and pelitic schists.

A better section of the Shyok melange can be seen on the eastern side of the Hushe valley and up the lower reaches of the Saltoro river.

This section starts at the confluence of the Shyok and Hushe rivers with typical ophiolitic melange, consisting of large and small fragments of serpentinite, basic and intermediate lavas pyroxenite, marble, red and black chert, porphyritic basalt, dacite, rhyolite, phyllites and gabbro. This passes up into a metamorphosed distal flysch section in which the grade of metamorphism increases northwards, culminating in interlayered biotite plagioclase gneisses and schists with thin marble layers and zones of serpentinite melanges. Dips gradually change from steeply north-eastwards to steeply south-westwards.

The succeeding units are in thrust slices directed north-eastwards over the Karakorum axial batholith complex. North of the metamorphosed flysch unit, is a thrust slice of dolomite marble, succeeded by an ultrabasic-basic slice of amphibolites, pyroxenites, and then a slice of quartz diorite. The quartz diorite is thrust steeply over the Karakorum zone to the north but the thrust sheets are themselves cut by quartz diorite intrusions with thin contact aureoles east of Tagas and at Huldi.

3. *The Karakorum axial batholith zone.*

In the Hushe valley, above the fault a Kande, a relatively uniform sequence of biotite-plagioclase augen gneisses, derived from quartz-diorites, stretches as far as Hushe. Between Hushe village and the terminus of the Masherbrum glacier are predominantly biotite-epidote gneisses.

Just north of a major normal fault cutting across the head of the Hushe valley a more diverse metamorphic series is exposed, consisting of banded quartz-feldspathic gneisses and pelitic gneisses, with some marble layers, amphibolite-biotite gneisses and quartz-feldspathic garnetiferous gneisses. At the terminus of the Masherbrum glacier rounded pebbles of fine-grained siliceous dolomitic marble are common in the moraine. These pebbles are identical in lithology to the 'limestone' from which cystoids were recorded by Verchère (1867), and it is tempting to accept this fossil record on that basis. However, until further fossils are found the presence of Ordovician carbonates in the Karakorum must remain uncertain (see discussion in Desio and Giobbi, 1974).

The upper Masherbrum valley is apparently formed of finegrained augen gneiss (Desio and Giobbi, 1974), possibly downfaulted against the lower grade metamorphic rocks to the south.

In the Saltoro valley, the Karakorum axial batholith zone starts with a major northwardly directed major overfold consisting of white fine-grained biotite gneiss, passing upwards into hornblende-garnet-biotite gneiss and schist. At Kondus, the fold is cut by quartz diorite intrusions and from there to the Saltoro Kangri Group and K6, the area consists of several major intrusions of quartz diorite and trondjemite, with patchy hornblende-quartz feldspathic gneiss and dioritic gneiss envelopes and pendents. At least two phases of intrusion can be seen at Khorkundus, where undeformed quartz-diorite cuts foliated quartz-dioritic gneiss at the hot spring. The intrusions are surprisingly uniform in composition, though showing a variety of textures.

Age relationships and tectonics.

For the Karakorum axial batholith zone, little can be added to the account of Desio and Giobbi, (1974), who recorded: a first dynamic phase giving the primary schistosity of the rocks, followed by an acidic intrusive phase accompanied by widespread anatexis, succeeded by a second dynamic phase causing

rotation of plagioclase poikiloblasts and deformation, and culminating in a final intrusive phase (Baltoro granite) and static recrystallization phase. At Khorkundus, the several phases of quartz diorite intrusion suggest a more or less continuous sequence of deformation and intrusion and metamorphism, which may have varied in time and place through the Karakorum.

At Brakhor, the post-metamorphic large overturned fold may be related to northward thrusting of the Shyok melange. There is no post-folding recrystallization or deformation of this fold which predates the intrusion of at least some of the quartz diorites to the north. The quartz diorites at Tagas and Huldi also testify that to the northward thrusting of the Shyok melange predate at least some of the Karakorum intrusions.

The Shyok melange shows two phases of metamorphism and deformation. The quartzo-feldspathic gneisses and schists near Huldi show rotated plagioclase porphyroblasts containing an early static phase of biotite crystallization. The amphibolites near Tagas show mortar textures probably related to deformation during the northward emplacement of the Shyok suture zone.

Immediately south of the Shyok suture zone, at Khaplu, the micro-dioriote dykes cutting the Ladakh–Deosai batholith complex seem to be post-southward emplacement of the Shyok suture zone. The mylonite zone of the Shyok suture zone also cut across the Ladakh batholith metamorphic rocks.

The ages of the deformations and metamorphisms can not yet be fixed; though a program of U/Pb and Ar^{40}/Ar^{39} dating is in progress. So far, dates from the Ladakh–Deosai batholith complex which pre-date the emplacement of the Shyok melange range from 15 to 48 myrs (Desio, 1964, 1976) (Lal and Nagpaul, 1975, Casnedi *et al.*, 1978); with the hornblende-grandiorite south of Khaplu giving a Ar^{40}/Ar^{39} age of 39 myrs. (late Eocene).

Published ages for the Karakorum axial batholith complex give Miocene ages (Desio, 1979). Thus the Shyok melange was apparently emplaced southward in post-late Eocene times then thrust northward after the main phases of the Karakorum axial batholith, i.e. in post-Miocene times.

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