The Main Mantle Thrust: Its Score in Metallogeny of Northern Pakistan

R.A. KHAN TAHIRKHELI

Abstract: Major shear zones in the collisional orogens like the ones exposed in Pakistan, can create important pathways for the movement of the mineralized solutions alongwith magmatic emanations. The Main Mantle Thrust (MMT), which has come to limelight recently, constitutes one of the important major tectonic scars on the northwestern terminus of the Himalaya. It extends for over 500 km across the northern part of Pakistan, welding the Indo-Pakistan plate with the Kohistan island arc. Several magmatic bodies, some of them of batholithic dimensions are associated with this megashear.

In this paper an attempt has been made to focuss upon the magmatic environments associated with MMT to discern various episodes of metallic mineralizations and their localizations in the subducted Indo-Pakistan marginal mass, obducted Kohistan mass and in the Main Mantle Thrust zone.

INTRODUCTION

The earlier contributions by Sillitoe (1978, 1979), shed ample light on the distributive pattern of five principal prospective mineralized zones associated with the shears created in the collisional mountain belts like Pakistan. His assumptions, though speculative, do provide a comprehensive overview of the regional mineralized mosaic, delineated by various tectonic episodes, during alpine and pre-alpine orogenies.

Recent discovery of the ancient Kohistan island arc in northern Pakistan has brought new additions to the prevailing concept of continental collision, aftermath suturing and subsequent tectonic architecturing in the Karakoram belt than envisaged in the rest of the Himalaya. This statement is corroborated by some of the following evidences gathered during recent years.

1. The absence of the Main Central Thrust in the Karakoram, which in the Himalaya so pronouncedly demarcates the boundary between the Lesser Himalaya and the Himalayan Crystallines.

2. The presence of Kohistan island arc on the northwestern terminus of the Himalayas which interplayed with the two mighty continental plates during collision and subsequent alpine orogenesis. The resultant affect is reminiscent in Kohistan, bounded by two suture zones, and intricate structures created in the marginal masses of both the continents and the Kohistan arc. Nowhere in Pakistan does the Eurasian plate come in direct contact with the Indo-Pakistan plate.

3. The bifurcation of the single Indus suture, as observed in Tsang Po, into two sutures in the western Ladakh which extends into Pakistan. The two sutures are differentiated as the Northern Megashear and the Main Mantle Thrust.

Under the context of these evidences and findings a new model on the alpine orogenesis and tectonics of Karakoram becomes imperative which, besides other geological factors, should accommodate the relationship of various igneous episodes and their role in inducting regional mineralizations. The earlier concept on this problem was based on one suture, but it needs to be further developed by including the second suture, the Main Mantle Thrust.

MMT has recently come into the limelight and thus more work is needed to unravel its all the relevant geological aspects in various sections, required to decipher metallogenic environment associated with this megashear. Whatever limited informations are available to the author at this stage will be accommodated in this paper to analyse the known and prospective mineral occurrences, which owe their origin to several magmatic episodes emanated through numerous macro- and micro fractures developed during and after collision.

THE GEOGRAPHICAL AND STRUCTURAL DOMAIN OF MMT

MMT was first deciphered near Jijal along the Karakoram Highway. Later on, its extensions were confirmed at several other sections; some of them are Shangla, Mingora and in the vicinity of Khar in the west; near Babu Sar Utla, west of Doian on Bunji-Astor road, near Sassi and east of Thawar along the Indus where it loops around Nanga Parbat-Haramosh

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antiform. Further east it takes a course through Astor and extends across the border towards Dras in the Western Ladakh.

The surfacial trace of MMT in most of the sections is diffused as a result of blurring by the younger superimposed structures and subsequent defacing of the incompetant rocks due to weathering. In three sections e.g. Shangla, Jijal and Babu Sar Utla, however, its surficial structural manifestations are clear.

MMT on the surface, usually covers 8-10 km wide zone which may enhance in some sections. The subsurface behaviour of MMT, as telemetered from the Tarbela Dam Seismic Observatory, reveals it to spread in 35-40 km wide zone below 10-12 km depth. In the earlier mentioned three sections in Hazara, Swat and Dir, MMT usually occupies topographic "high", which usually coincide with the overthrusted block of the Kohistan zone. The thrust dips northward at medium to low angles but in some sections the deformations of later periods have affected the original angle of inclination.

PRINCIPAL ROCK ASSOCIATIONS

The northern fringe of the Indo-Pakistan Plate, as indicated earlier, exposes widespread metasedimentary suite of rocks ranging from slates to various types of schists, paragneisses and migmatites. The metamorphism gradually increases from south towards MMT, in the north. The kata-zones exposing para-amphibolite, foliated gneisses with augen structure and migmatites become frequent in occurrences in the Indo-Pakistan marginal mass in the vicinity of MMT.

Among the schistose rocks, the prominent ones are those of mica schist, quartz schist, garnet schist, carbonate schist, graphitic schist, staurolite schist, kyanite schist, green-schists, glaucophane schist with marmorised carbonate bands. Some of the gneisses especially those associated with the Hazara syntaxial bend in the Kaghan Valley, and those forming the core of the Nanga Parbat-Haramosh antiform, are sillimanite-bearing.

The metasedimentary sequences are intruded by the acid and basic igneous bodies, the former have vast expanse in Hazara, Swat and Dir. Among the basic rocks diorite, dolerite and gabbro are noteworthy and occur as sills and dykes but some may occur in larger dimension.

Granites, granodiorite, pegmatite, aplite and vein quartz constitute the major acid igneous emanations associated with the Indo-Pakistan marginal mass. They are enveloped by some of the major regional structures, such as Hazara-Kashmir syntaxis and Nanga Parbat-Haramosh antiform. Some of the igneous bodies, such as those of Shilman and Warsak (Khyber Agency), Malakand, Koga (Buner), Utla (Gadun area in Swabi) and Tarbela Dam (on the right abutment) have been differentiated to be alkaline, forming a semi-circular bend, skirting the rest of the igneous bodies on the south.

The Kohistan Mass obducts the Indo-Pakistan Plate along the Main Mantle Thrust. The rocks exposed in Kohistan include amphibolites, peridotites, garnet granulites, pyroxene granulites, andesite, dacite and rhyolites, greenstone complex, diorites, granodiorites, granites and scores of veins, sills and dykes of younger acid and basic intrusives. The metasedimentary rocks in Kohistan belong to Cretaceous-Lower Tertiary and are comprised of slates, schists, quartzitic-sandstone with chert and semi-crystalline limestone which form isolated outcrops and have been differentiated as Kalam Group, Dir Group and Chalt Formation.

Amphibolite occurs along the MMT and form an overthrust mass along the thrust plane. The peridotites occur in large bodies in the shear plane in the vicinity of Dras across the border in Ladakh and between Jijal and Shangla which extends east of the Indus in Allai area. Another peridotite body forming a klippe is exposed further south near Dargai in Malakand-Mohmand area.

Elsewhere the ultramafic rocks are found strewing both the subducted and obducted masses, forming small isolated bodies all along the thrust, being more frequent in distribution in the obducted mass. The peridotites are considered to have been tectonically lifted from the upper mantle.

For a detailed description of the rocks of Kohistan Mass, the author suggests the readers to go through a recently published monograph on the Geology of Kohistan, Karakoram Himalaya, Northern Pakistan (Tahirkheli and Jan, 1979).

INDICATED AND PROSPECTIVE MINERAL ASSOCIATIONS

Among the igneous intrusives, the basic igneous bodies have relatively little contribution to mineralization in the subducted Indo-Pakistan marginal mass. Because of their basic nature and small size, these bodies could not cause metallic mineralization on a large scale. On the other hand, the acid and intermediate igneous bodies associated with the Indo-Pakistan Plate margin and Kohistan zone because of frequent traction by comparatively mineral rich hydrothermal solutions, vaste expanse and contact with a great varieties of rocks were more effective in mineral formation on regional scale. Therefore, most of the known mineral occurrences show a sympathetic genetic relationship with these rocks.

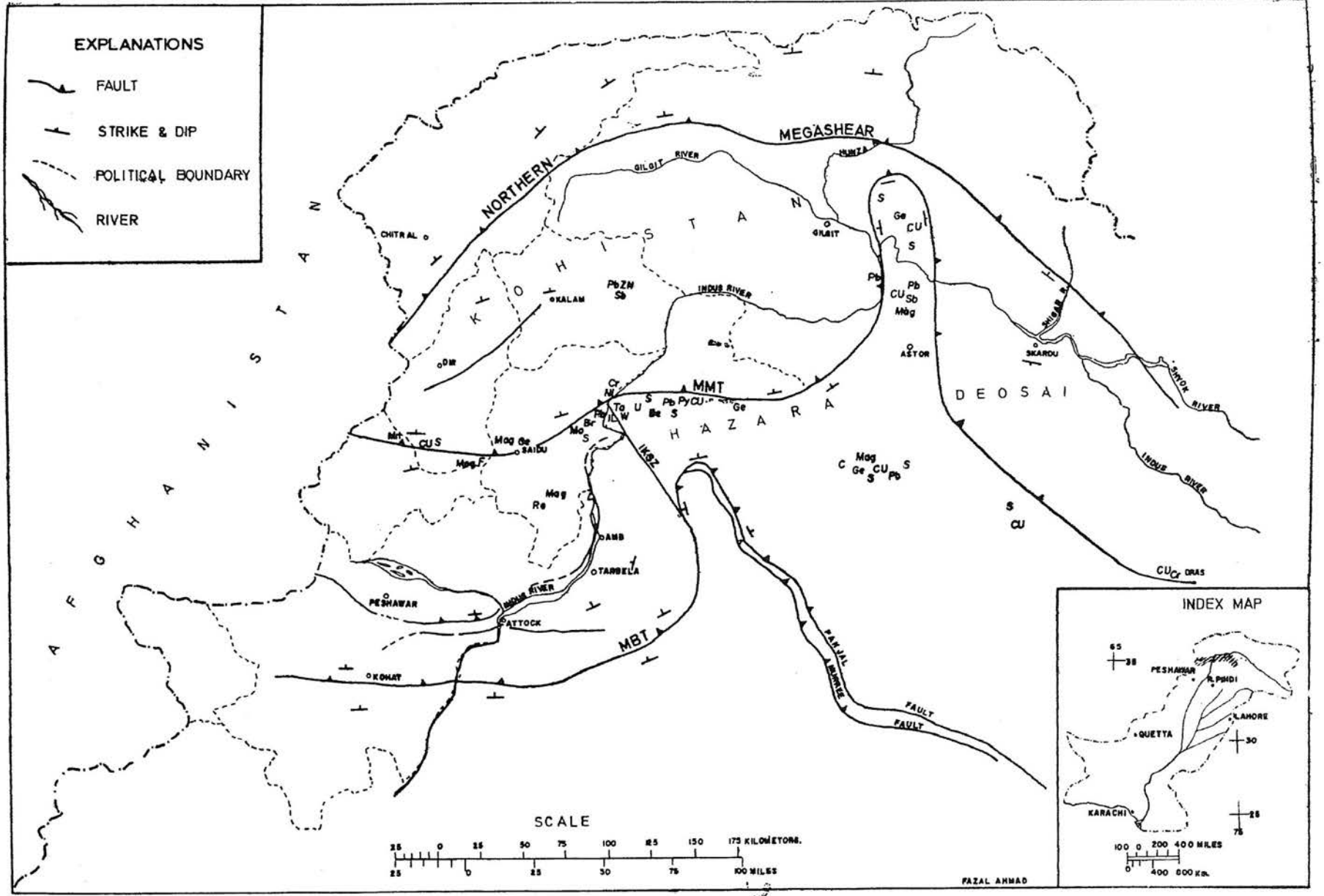

FIG: 1. KNOWN MINERAL OCCURRENCES ASSOCIATED WITH MAIN MANTLE THRUST

1. ANTIMONY – Sb, 2. BARITE – B, 3. BERYL – Be, 4. CHROMITE – Cr, 5. COPPER – CU, 6. FLUORITE – F, 7 GALENA – Pb, 8. GEMS – Ge, 9. GRAPHITE – C, 10. ILMENITE – IL, 11. MANGANESE – Mn, 12. MAGNETITE – Mag, 13. MOLYBDENUM – Mo, 14. NICKEL – Ni, 15 PYRITE – Py, 16. RARE EARTHS – Re, 17. SCHEELITE – W, 18. SPHALERITE – ZN, 19 SULPHIDE MINERALIZATION – S, 20 TENTALITE – Ta, 21. URANIUM – U,

(MINERAL LOCATION APPROXIMATE)

In Kohistan, which constitutes the obducted part of the arc along MMT, the composition of acid and basic rocks, their distribution and poly-phased deformations, as a result of interaction with the two mighty continents during and after collision, the regional geological set-up produces a bright prospect for the generation of minerals than the Indo-Pakistan mass. Here huge thickness of calc-alkaline, volcanic, mafic and ultramafic rocks of various denominations are encountered, some of which were generated under high temperature and pressure. The granitic bodies representing the last phases of alpine orogeny have also widespread distribution in Kohistan.

The known minerals occurrences associated with the MMT zone are categorised into three parts; A. Minerals associated with the subducted Indo-Pakistan marginal mass, B. Minerals occurring in the obducted Kohistan complex and, C. Minerals localized in the tectonically lifted peridotite bodies emplaced in the suture zone or transported elsewhere as klippe.

A. Mineral occurrences in Indo-Pakistan subducted marginal mass

Kashmir — east of the syntaxial belt in Nilam Valley:—

Hydrothermal graphite, galena, antimony, copper, magnetite, uranium, beryl, semi-gems etc.

The terrain formed by Nanga Parbat-Haramosh antiform have high altitudes and is inaccessible except through large valleys. The local inhabitants living in these valleys have shown specimens of the following minerals which were collected from widely scattered area.

Copper (chalcopyrite, azurite, chalcocite, malachite), galena, antimony, magnetite, heamatite, barite, etc.

These minerals were collected by the shepherds from this area and reflect upon the nature of mineralizations expected in the protruding tongue of the Indo-Pakistan Plate.

Hazara:— West of the syntaxis

Chail Sar: beryl-bearing pegmatite.

Oghi-Nilishang area: scheelite, uraninite, biblinite, ilmenite, tentalite, columbite, uranium in graphitic schist near Takot.

Hal: galena, pyrite, chalcopyrite, barite.

Mihal: galena, pyrite, chalcopyrite, barite

Sherwan-Galiat area: barite, galena, magnetite, some copper showings in the quartz veins

Kacchi area—north of Haripur: barite, galena, chalcopyrite, azurite, magnetite, associated with the hydrothermal veins in the Tannawal Formation.

Swat:— Emerald mineralization of Mingora, rare earths associated with Koga and other alkaline complexes.

Dir:— Fluorite of Chakdarra, magnetite, galena, chalcopyrite.

B. Mineral occurrences in Kohistan

As stated earlier, this is the least explored area for the minerals. Some of the known mineralizations occurring in the close vicinity of MMT are as follows:

Across the border in Ladakh:— disseminated chalcopyrite and native copper veinlets associated with the Dras volcanics.

Astor Area:— galena, chalcopyrite, chalcocite, sphalerite, molybdenite, magnesite associated with the Ladakh Granodiorite and Copper in the Deosai volcanics.

Chilas-Bunji area:— pitchblende, semi-gems, several erratic sulphide mineralizations in Bagrot and adjoining areas in Gilgit part of Kohistan.

Thalichi:— lead, antimony, copper.

Swat Kohistan:— polymetallic deposits (antimony-lead-zinc) of Ushu associated with the east-west trending shears; pyrite, copper, magnetite, manganese associated with the Utror volcanics.

Dir Kohistan:— chalcopyrite, bornite, pyrite; manganese, magnetite in Bajaur area.
Usheri: chalcopyrite, bornite, pyrite.

C. Minerals associated with the peridotite complexes

There are three large peridotite bodies, two of them e.g. Jijal-Alpuri and another near Dras across the border, are emplaced along the MMT zone whereas the third one near Dargai is a transported block and forms klippe.

Dras:—chromite, magnetite.

Jijal-Alpuri:— chromite, nickle, magnetite.

Dargai:— chromite, magnetite, magnesite, asbestos.

DISCUSSION

On the basis of metallogeny associated with various orogenic phases, which are related to MMT, three regional tectonic settings may be differentiated in the northern parts of Pakistan. These are: i. Subducted Indo-Pakistan Plate marginal mass ii. Main Mantle Thrust zone and iii. The obducted Kohistan mass.

Several magmatic episodes are associated with the continental marginal mass in Pakistan which belong to both pre- and post continental collisional periods. Among the former, on the basis of scattered dates obtained on the granites by several workers, an age range from 80 m.y. to 560 m.y. (last date by LeForte, 1979) were obtained. These dates place the granite magmatism between Early Palaeozoic to Late Mesozoic. As this paper is intended to deal with the metallogeny associated with the MMT, the magmatism generated during and after continental collision will be limelighted. Nevertheless, it may be mentioned here that the granitic bodies of later age, associated with the post-collisional orogenesis and responsible for generating mineralization in this region, have also intruded the metamorphic rocks and the earlier stated older granites of the underthrusted marginal mass of the Indo-Pakistan Plate, located south of MMT. Still thorough observations are to be made to decipher various mineralized environments, but those which have been differentiated so far are, i. The acid minor bodies consisting of pegmatite, aplite and quartz including some scattered granites strewing the higher grade metamorphic rocks north of Mansehra in Hazara and in Lower Swat, ii. Hydrothermal mineralization associated with the pegmatite and quartz veins in Chakdarra foliated granite in Dir, iii. Barite-lead and other minor metallic mineral showings associated with the Karora (Lahor) granite in Alpurai-Allai area in Swat and iv. hydrothermal graphite and other minor metallic minerals associated with the granite and granite gneises in the upper reaches of the Nilam Valley in Kashmir. The former three localities are situated west of the western syntaxis whereas the last one is located on its east.

The reflections on the order of emplacement of these bodies, based on field evidences in various sections, placing the younger in descending order, is some granite bodies intrusive into the metamorphics and older granite, pegmatite, aplite and quartz. The hydrothermal emanations are usually syngenetic with the formation of pegmatite, aplite and quartz but in some cases have indicated a younger phase subsequent to the formation of the acid minor bodies, because in many sections these rocks display signs of aftermath effect of circulating fluid, at places giving rise to telethermal ore showings. Not only that, even the schistose rocks near the margin in the vicinity of MMT also show evidences of hydrothermal fluid circulation. Such sections emit sulphuretted smell and contain sporadic sulphide mineral showings, pyrite being abundant.

The Main Mantle Thrust zone, as indicated earlier has 8-10 km wide surficial expression, which incorporate slices of metamorphic rocks of the continental marginal mass intruded by granites and some acid and basic minor bodies. The noteworthy feature of this zone is the presence of peridotite bodies emplaced along the fracture zone, which have relatively higher densities than the surrounding rocks and are being considered to have been tectonically transported from the upper mantle. There are many such smaller bodies associated with the MMT zone but the ones which are extensive in distribution and have potential for having economically exploitable mineral occurrences are, i. across the border in the east, in the vicinity of Dras in Ladakh, ii. Alpurai-Jijal-Allai area in Swat-Hazara and iii. Dargai klippe, located south of MMT in Malakand. The known mineral occurrences in these bodies have already been cursorily discussed earlier, but still a lot of work is required to decipher these mineral associations which have so far not been brought within the fold of geological observations. At Jijal, the peridotite body forms part of the over-riding Kohistan Mass and thus was tectonically emplaced during the early phases of subduction of the Indo-Pakistan Plate. This evidence relates the generation of the peridotites with the suturing subsequent to continent-continent collision, and this magmatic phase may be considered to be the earliest.

The magmatic evolutionary history of the Kohistan Mass, which over-rides the Indo-Pakistan Plate a'ong MMT is varied and complex. Its calc-alkaline plutonic and volcanic rocks post-date the major orogenic events, as a result, the generation of mineralization by hydrothermal emanations may be associated with several magmatic episodes.

In such environment polymetallic nature of mineralization is one of the characteristic feature which is evident in Ushu valley in Swat Kohistan where complex ore of antimony-lead-zinc occurs in associations with the diorites. As mentioned earlier, Kohistan constitutes one of the least explored segment of the northern Pakistan and still a lot of work is required to locate and decipher various magmatic episodes with which mineralization in associated. However, comparing it with the already known areas of the world, having similar geological environment, one may expect Kohistan to stand a good chance for being considered a rich metallogenic province. In support of this view some examples may be quoted.

The Utror volcanic arc—which is mainly composed of andesite, dacite and rhyolite appears to be suitable for Kuroko type stratiform sulphide mineralization

like zinc, copper, lead, silver and manganese. So far copper, magnetite and manganese mineralizations have been recorded in these rocks near Gabrial in Swat and north of Khar in Dir.

Similarly in the diorite plutons of Kohistan four varieties of diorites have been differentiated. Among them the quartz diorite is quite widespread. In Soloman island, gold is associated with this type of diorite.

The mafic layered complex in Thak valley in the vicinity of Chilas and in the northern margin of Kohistan has so far not been investigated for its economic potential. Such layered complexes elsewhere in the world e.g. Bushveld complex in South Africa have yielded many economic minerals like platinum, nickel, chromite including a few others. Thus the layered complex of Kohistan which has vast spatial distribution could prove its potential for such economic minerals.

The minerals or mineralized zones described above occur mainly as disseminations, lenses, veins or pods either filling the interweaving ancillary fractures associated with the MMT zone or otherwise found intermingled with the rocks where the mineralizations were introduced by various older phases of igneous emana tions. The minerals reported may not be economical to warrant large scale exploitation at this stage, but some of them have potential to become economical, if a scientific base pertaining to detail evaluation of controls on structure, petrology and paragenesis are laid to decipher their localizations and mode of subsurface behaviour. Thus at this level, till such studies are complete to give these mineral occurrences a status of deposits, the author would describe them as "minerals showings".

These minerals showings, some comprising zones may not be underestimated because of their surficial lean behaviour. They depict a gigantic process of movement of mineralized molten solutions from deep beneath the surface (some as deep as upper mantle) to the surface, which should have taken millions of years and due to changing environment enroute, might have become saturated by winning many minerals from the rocks through which it passed. Thus whatever is seen on the surface may not necessarily be the same as found eclipsed at the deeper horizons.

So far, Pakistan lacks this type of approach to decipher its metallogenic provinces. MMT could score a point on other such megashears because of relatively less development of crustal telescroping after continental collision. Thus the chances of finding subsurface localizations of minerals along this megashear will be relatively at shallower depth, technically less cumbersome to reach and comparatively less expensive to exploit.

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