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HIMALAYAN AND TRANSHIMALAYAN GRANITIC ROCKS IN AND ADJACENT TO NEPAL AND THEIR MINERAL POTENTIAL

A. H. G. MITCHELL

HMG/UNDP Mineral Exploration Project, Lainchaur, Kathmandu, Nepal.

ABSTRACT

Granitic rocks occupying eight distinct tectonic settings can be recognized in the Himalayas and Transhimalayas. In the Lower Himalayas geographical belt a few plutons of two–mica granite intrude the lowest unit of the Nawakot Complex or Midland Group. More extensive are sheet–like bodies of augen gneiss intrusive within a possibly thrust–bounded succession of carbonates and graphitic schists beneath the Main Central Thrust to the north. The most abundant granites in the Lower Himalayas are the two–mica cordierite–bearing granites within klippen; minor tin and tungsten mineralization is associated with these plutons, which are of late Cambrian age. Within the Higher Himalayas above the Main Central Thrust, the 'Central Crystallines' or Central Gneisses include pegmatites and pegmatitic granites intrusive into gneisses of probable early Proterozoic age; these have same potential for ruby, sapphire, aquamarine and possibly spodumene. Further north within the Higher Himalayan succession a southern belt of anatectic two–mica granites and leucogranites of mid–Tertiary age is favourable for tin, tungsten and uranium mineralization; a northern belt of granites or gneisses is of uncertain age and origin. North of the Indus Suture in the Transhimalayas extensive batholiths of hornblende granodiorite representing the root zone of a late Mesozoic to early Eocene volcanic arc are associated with porphyry copper deposits. Further north in southern Tibet the tectonic setting for reported granitic bodies of Tertiary age is uncertain; their location suggests that they could be favourable host rocks for tin, uranium and porphyry molybdenum mineralization.

INTRODUCTION

It has long been recognized that the Himalayas and adjacent Transhimalayas to the north contain numerous granitic bodies. While some of these granites were recognized many years ago as being related to the Himalayan orogeny (Gansser 1964), there was until recently little evidence for the age of some of the other major granitic plutons. In the last five to ten years radiometric age determinations based on Rb/Sr whole rock isochrons, combined with geological mapping in particular by Le Fort (1975), Le Fort et al (1980) and Gansser (1977), have resulted in more information on the ages of the granites, their genesis, and the delineation of granitic belts. Moreover, although only the Transhimalayan granites are associated with known economic mineral deposits, the new data yield information on the mineral potential of the Himalayan granites also.

In Nepal and the adjacent parts of the Himalayas and Transhimalayas granitic rocks within eight different tectonic settings (Fig. 1) can be recognized. These are described below, mostly in sequence from the structurally lowest to highest, which corresponds very broadiy with their position from south to north.

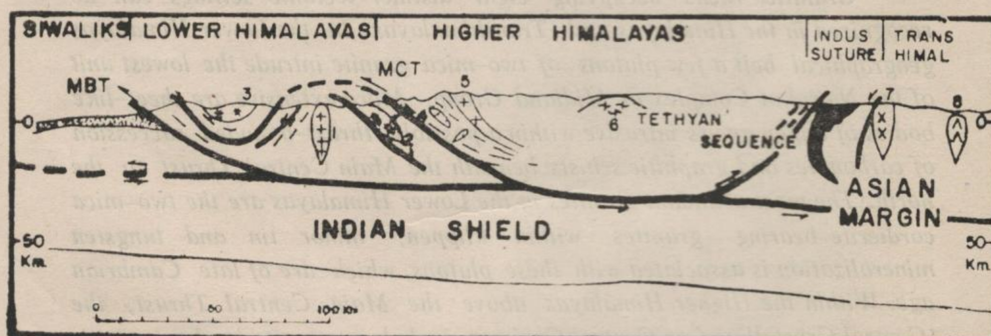

Fig. 1. Schematic cross-section through Himalayas and Transhimalayas, modified from Le Fort (1975). 1–granitic rocks intrusive within the Lower Himalayan sequence; 2–augen gneiss south of the MCT; 3–granites within klippen of Higher Himalayan rocks: 4–granitic rocks of the Central Crystallines; 5–southern belt of Higher Himalayan leucogranites; 6–northern belt of Higher Himalayan granitic rocks; 7–calcalkaline granodioritic plutons of the Transhimalaya; 8–granitic ring complexes of southern Tibet. MCT–Main Central Thrust; MBT–Main Boundary Thrust.

GRANITIC ROCKS OF THE LOWER HIMALAYAS

Granites intrusive within the Lower Himalayan sequence

A few bodies of weakly foliated to gneissic granitic rock have been reported (Chakrabarti, pers. comm. 1979; Mineral Exploration Project, unpub. report) from the lowest stratigraphic unit of the Nawakot Complex in Central Nepal. These are mostly biotite or biotite-muscovite granite and adamellite intrusive into lower greenschist facies flysch-type host rocks of the Kuncha Fm. No economic mineralization is known from the granites although adjacent to them occurrences of thorium and uranium have been reported. The granites presumably pre-date the Himalayan metamorphism.

Augen gneiss south of the Main Cent al Thrust

The most strongly metamorphosed of the Himalayan granitic rocks, and possibly also the oldest, comprise a discontinuous zone of gneisses a'ong the northern margin of the Lower Himalayan geographical belt (Hashimoto et al, 1973). The gneisses have been described in most detail from Central Nepal.

In eastern Central Nepal Hashimoto et al. (1973) showed the Melung Augen Gneiss as forming northward-inclined to flat-lying broadly conformable sheets up to 2000m. thick in the northern part of the lower Himalayas. They described two-mica gneisses and granitic gneisses with potash feldspar augen and minor plagiocalase noted local mylonite within and at the gneiss boundaries; tourmaline–bearing pegmatites were reported from within the gneiss. Hashimoto et al, mapped three thrusts south of the Main Central Thrust beneath the Central Crystallines, and considered the upper and lower surfaces of the augen gneiss to be bounded by the middle and northern thrusts. The gneisses were interpreted as a thrust sheet of the inferred Precambrian basement.

In western Central Nepal, Le Fort and Pecher (1974) and Pecher and Le Fort (1977) described in more detail the augen gneisses mapped by Hashimoto et al. (1973), and termed them the Ulleri Augen Gneiss. In general this gneiss has a granitic chemical composition with both potash feldspar and albite augen; wide variations in K_20/Na_20 ratio prevent overall classification in terms of a particular granitic parent.

Le Fort and Pecher (1974) and Pecher and Le Fort (1977) considered the augen gneisses of Nepal to be meta-volcanic rocks, largely on the basis of transitional contacts with host rocks, intercalations of schists, quartzites and meta-conglomerates, occurrence of bluish quartz grains, and variable K_20/Na_20 ratio. They considered that the gneisses resulted from metamorphism of felsic volcanic rocks erupted in the Middle or Lower Palezoic.

Field work by the Mineral Exploration Project (unpub. report) in eastern and eastern central Nepal indicates that the augen gneisses show a sharp upper and lower contact with adjacent schists, but that they are thrustbounded only locally along their lower surface. The presence of more or less identical schists and carbonates above and below the gneisses also suggests that the gneisses are in most places not bounded by thrusts with major displacement. The graphite schists, marbles, tremolite schists and quartzites in which they occur cannot be stratigraphically correlated with the Lower Nawakot Group to the south, even if their higher metamorphic grade is allowed for, as suggested by Pecher and Le Fort (1977 and Stocklin 1980); they are also dissimilar to rocks of the Kathmandu Complex Nappe or klippen. This suggests that the gneisses and immediately overlying and underlying succession either from a thrust sheet beneath the Main Central Thrust but lying structurally above the Kuncha Formation (Fig. 1.), or that the successiona djacent to the gneisses is equivalent to the Benighat Fm. of the Upper Nawakot Group and lies unconformably on the Kuncha Fm. (Fig. 2).

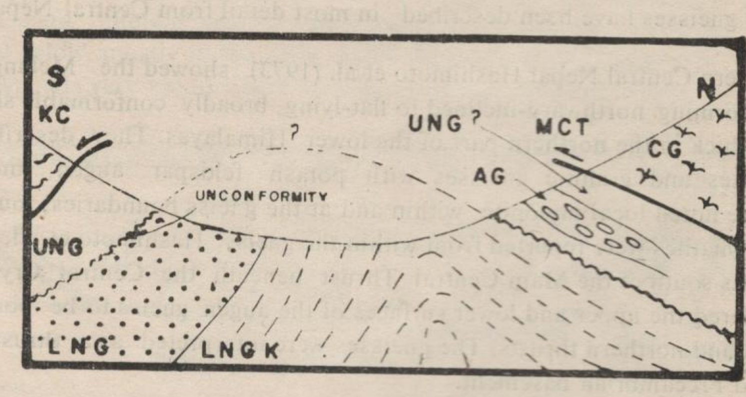

Fig. 2. Schematic cross–section, Lower Himalayas of Nepal, showing augen gneiss intrusive into rocks interpreted as Carboniferous–Permian Upper Nawakot Group. An alternative interpration to that in Fig. 1. AG Augen gneiss within ? Upper Nawakot Gp; CG Central gneiss; KC Kathmandu Complex; LNGK–Lower Nawakot Gp (Kuncha Fm.); LNG–Lower Nawakot Gp (Fagfog, Dandagaon, Nourpul, Dhading Fms); MCT Main Central Thrust; UNG Upper Nawakot Gp (Benight Slate etc.).

Possible correlatives of the augen gneisses of Nepal noted by Pecher and Le Fort (1977) are the gneissic quartz porphyry of Ramgarh in the Kumaon Himalayas (Heim and Gansser, 1939) and the Chipalkot augen gneisses of NE Kumaon which are associated with limestones and graphitic slates (Powar, 1972) comparable to those in Nepal. In the South Lahul area of the Kumaon Himalayas Frank et al. (1977) have referred to granites and meta–rhyolitic rocks intercalated with the Berinag white quartzites and meta–basics of the Chail Nappe lying structurally beneath the Central Crystallines; possibly the meta–igneous rocks could be equivalent to the augen gneiss of Nepal,

No significant mineral occurrences are known from the gneisses, although arsenopyrite and minor copper sulphide have been reported from the upper boundary of the gneiss by the Mineral Exploration Project in Nepal. If the gneisses are metamorphosed acid volcanics, they should be either volcanic arc rocks, with potential for stratiform Zn–Pb–Cu sulphides of Kuroko–type as suggested by Mitchell (1979), or riftrelated volcanics as suggested by Sillitoe (1980), with the possibility of stratabound copper mineralization. However the sharp contacts of the gneisses with adjacent schists, and presence of large K–feldspar phenocrysts within a zone of regional metamorphism not above garnet grade, suggests that they are sheetlike bodies of intrusive granitic rocks subsequently metamorphosed to gneiss. The deep erosion level indicated by the gneissic texture provides a strong indication that hydrothermal deposits related to either intrusion or cooling of the granite are unlikely to be present.

The gneisses clearly pre–date the Himalayan metamorphism, although this does not rule out an Oligocene age. Possibly they are of similar age to the late Cambrian granites of the Higher Himalayan klippen described below; alternatively, they may be equivalent to the meta–igneous rocks of Berinags referred to above, which have yielded a Rb/Sr whole rock isochron age of 1840 ∓ 70 my (Frank et al., 1977).

Granites within klippen of Higher Himalayan rocks

Granitic rocks and gneissic granites have long been known from within the crystalline thrust sheets or klippen of the Kumaon Himalayas (Gansser, 1964) and were dsecribed by Hagen (1969) and Stocklin (1980) from the Kathmandu Complex in Nepal. These granites are mostly weakly foliated to gneissic and sometimes massive inclined slab–like bodies confined to areas of meta morphic rock which lie within the Lower Himalayas geographical zone, and which are interpreted as klippen of Higher Himalayan rocks lying structurally above the Lower Himalayan sequence.

Le Fort et al. (1980) have recently referred to granites of this type, extending from Pakistan to eastern Nepal, as the "Lower Himalayan" cordierite granite belt, characterised by two-mica granites commonly with tourmaline. The Manserah pluton in Pakistan is mostly a coarsely porphyritic medium–grained two-mica granite with large crystals of cordierite; minor granodiorite also occurs. The plutons of Far West Nepal and the Kathmandu Complex are porphyritic two-mica granites and leucogranites with variable tourmaline content. The granites everywhere show abundant metasedimentary xenoliths and in the Manserah pluton include micro-granular inclusions. Host rocks are metasedimentary and the granite generally shows intrusive contact.

The Manserah granite has yielded a Rb/Sr whole rock isochron age of 516 ∓ 16 my or Upper Cambrian, with aninitial Sr^{87}/Sr^{86} ratio of 0.719 (Le Fort et al., 1980). An age determination arranged by the Mineral Exploration Project on the

Palung Granite in the Kathmandu Complex of Nepal has recently yielded a 486 ∓ 10 my Rb/Sr isochron age, with an initial Sr^{87}/Sr^{86} ratio of 0.720 (R. Beckinsale, pers. comm. 1980). The Palung Granite intrudes metasedimentary rocks considered to be of late Precambrian or possibly Cambrian age (Stocklin, 1980). Frank et al. (1977) reported a Rb/Sr age of 512 ∓ 16 my with an initial ratio of 0.710 for an intrusive granite within the Lahul crystalline nappes. Le Fort et al. (1980) noted the similarity of the granites to the 'S type' anatectic granites of White and Chappell)1978).

Minor tin and tungsten mineralization is known to be associated with the granites in Nepal (Talalov, 1977). Wolfram occurrences are known from the Manseral pluton, and in the schists a few hundred metres above the buried surface of the northward-dipping Dandeldhura Granite in Far West Nepal there is a copper sulphide–tungsten prospect and a cassiterite sulphide prospect. However a genetic relationship between these prospects in Nepal and the granite has yet to be proved, as it is conceivable that the mineralization could be a volcanic exhalative in origin as proposed for similar mineralization on Billiton Island in Indonesia, and hence older than the granite. In the Kathmandu Complex of Nepal, a number of occurences of casseterite are known from the margins of the granites, and minor greisenization is visible.

The late Cambrian age for the granites provides strongevidence for a Cambrian Orogeny in the Himalayas, as argued by Fuchs (1968, 1977) and others, although the precise tectonic setting for granite emplacement remains uncertain. The granites are unlikely to have formed in a subduction-related Cambrian magmatic arc because their high initial Sr^{87}/Sr^{86}ratio is atypical of Cenozoic magmatic arc rocks. It seems more probable either that they were generated in a back-arc magmatic belt during late Cambrian southward subduction beneath northern India, and were analogous to the back-arc Tertiary granites of Bolivia, or that they formed in a foreland-thrust belt during late Cambrian collision of India with anarc system to the north following northward subduction of ocean floor. In the latter case they would be analogous in origin, but not in age to the much younger Tertiary collision-related anatectic granites of the Higher Himalayas. In either case it could be argued that the granites were generated in a Cambrian thrust belt which was later reactivated following the early tertiary Himalayan collision.

Similarities between the Higher Himalayan sedimentary succession and that of western Southeast Asia suggest that Southeast Asia lay adjacent to northern India in the Cambrian (Mitchell, 1979). The western margin of Southeast Asia includes Cambrian volcanic arc rocks bordered to the west by a probable suture zone. It can be speculated that subduction of ocean floor beneath western Southeast Asia was followed by late Cambrian collision with northern India, then in Gondawanaland, resulting in generation of the "Lower Himalaya" granites in a foreland-thrust belt situated several hundred kilometres south of the northern margin of India.

GRANITIC ROCKS OF THE HIGHER HIMALAYAS

Granitic rocks of the 'Central Crystallines'

The 'Central Crystallines' unit or Tibetan Slab (Le Fort, 1975) lies immediately above the Main Central Thrust zone, at the base of the Higher Himalaya, Tibetan or Tethyan sedimentary succession. The crystallines consist largely of schists, gneisses and calcareous rocks of sedimentary origin and locally of sillimanite grade; three phases of deformation have been recognized, the first two involving isoclinal folding (Bordet et al., 1975). Migmatites and numerous small bodies of leucogranite and pegmatite are present locally, commonly with abundant tourmaline; granitic sills similar to those in the gneisses locally intrude the lowest part (? Cambrian) of the Tethyan succession. Serveral occurrences of polychrome tourmaline and aquamarine, reportedly with sapphire and rarely ruby, occur within coarse-grained pegmatites, the corundum being in some cases associated with carbonates, and spodumene was reported by Heim and Gansser (1939).

Many authors consider the granitic bodies and pegmatites to be of Tertiary age and related to heating and metamorphism associated with the India–Asia collision and movement on the Main Central Thrust. The gneissic host rocks underlie Ordovician rocks of the Higher Himalayas without an obvious structural break, suggesting a Precambrian metamorphic age. An early Precambrian age for the gneisses is supported by a Rb/Sr whole rock two-point isochron of 1895 ∓ 100 my on augen gneiss above the Main Central Thrust in the Kumaon Himalayas (Bhanot, Singh, Kausal and Thakur, 1977) and it is of interest that granite gneiss from the Askot klippen to the south yielded a Rb/Sr whole rock isochron of 1960 ∓ 100 my, (Bhanot, Pandey, Singh and Thakur, 1977) suggesting equivalence of the Askot klippen and the Central Crystallines. Whether the granites and pegmatites within the gneisses are of Lower Proterozoic age or younger remains uncertain.

Southern belt of Higher Himalayan leucogranites

In the Higher Himalayas a chain of granitic rocks extends from Bhutan nearly to the Sutlej river in the Kumaon Himalayas, and includes the granite on the south slope of Mt. Everest, the Manaslu pluton in Central Nepal, and the Badrinath Granite. These plutons lie mostly 100 to 150 km south of the Indus suture, and intrude the Phanerozoic succession above the Central Gneisses (Gansser, 1977).

The plutons are mostly leucogranites with two micas and tourmaline, and have been described by Gansser (1964), Le Fort (1975) and others. Le Fort (1975) described the Manaslu Granite as a north dipping slab more than 10 km thick, comprising a two-mica tourmaline-bearing core with pronounced foliation surrounded by a fine-grained rim often rich in tourmaline. It is mostly bordered by a dense network of granitic, aplitic and pegmatitic dykes up to several kilometres wide within the metasedimentary host rocks. No contact aureole is present. The Manaslu and other similar granites in Nepal (Le Fort, 1975) are aluminous alkali-rich leucogranites, with abundant muscovite and presence of aluminosilicates with persistent tourmaline, abundant apatite relative to zircon, and scarity of opaques. Locally the borders and tops of the granites show albitisation, muscovitization or greisenization, silicification and tourmalinization, indicating hydrothermal activity.

The granites intrude rocks of Jurassic age in Bhutan and Cretaceous in Nepal (Le Fort, 1975), and Gansser (1964) considered them to be of Miocene age. A mid-Tertiary age is supported by K/Ar age determinations (Le Fort, 1975) and by a Rb/Sr whole rock isochron age of 28 my with an initial Sr^{87}/Sr^{86} ratio above 0.74 (Hamet and Allegre, 1976). The high Sr^{87}/Sr^{86} ratio supports previous views that the granites are anatectic and the result of partial melting of continental rocks at depth, probably in the Tibetan Slab. Andrieux et al. (1977) favoured an origin by partial melting along the Main Central Thrust at a depth of around 35 km. The source of heat for the melting is uncertain; the postulated shear heating favoured by Andrieux et al. has been considered inadequate by Toksoz and Bird (1977), but no other satisfactory source has been suggested. No economic deposits are known from the granites, but Le Fort (1975) noted boulders with minor disseminations of sulphides derived from the Manaslu Granite, and pyrite, chalcopyrite, arseno-pyrite, sphalerite, galena, bismuthinite, and molybdenite have been reported in pegmatites at the granite margin.

The greisenization suggests that tin or tungsten mineralization might be expected, and it has been argued that the granites are analogous to those in the tin fields of Southwest England and the Main Range Malaysia (Mitchell, 1974, 1977). In particular, the granite mineralogy, tectonic setting and initial Sr^{87}/Sr^{86} ratio are similar to the tin-bearing granites of the Main Range Malaysia and north central Thailand. The granites have also been compared to the Devonian granites of the Massif Central in France in which uranium ore bodies are present, and Le Fort (pers. comm. 1980) has reported high uranium background values for the Manaslu Granite.

While the Higher Himalayan granites might thus appear to be possible hosts for economic deposits of tin, tungsten and uranium, Sillitoe (1979) suggested that the granites were emplaced at a structural level too deep for generation of mineralizing hydrothermal solutions. Evidence that tin and uranium mineralization in granites is related to circulation of post–magmatic hydrothermal solutions suggests that the Himalayan granites may be also too young for these mineralizing fluid to have been active. On the other hand, mid–Tertiary granites in Bolivia at elevations approaching those of the Himalayan granites contain significant deposits of tin and silver ores, suggesting that an Oligocene or Miocene age does not necessarily rule out the possibility of economic mineralization being present.

Northern belt of Higher Himalayan granitic rocks

Gansser (1977) shows a belt of granites in the Higher Himalayas of Tibet extending from north of Bhutan to northwest of Kathmandu and lying about 50 km south of the Tsangpo suture, well to the north of the southern belt of granites described above. There appears to be very little information on the composition or age of these granites. Gansser (1977) referred to them as granite and gneiss uplifts in the Tethys Himalays, and it may be that the they all occur within Precambrian basement. No reports of mineralization are known from these granites.

GRANITIC PLUTONS OF THE TRANSHIMALAYAS

Calc–alkaline granodioritic plutons

North of the Indus–Tsangpo suture granitic plutons form a major belt, locally in tectonic contact with the ophiolitic rocks of the suture. The granites are predominantly hornblende–bearing granodiorites and tonalites, lacking a metamorphic foliation; their composition thus contrasts with that of the Higher Himalayan leucogranites to the south. K/Ar radiometric ages reportedly range from 95 to 37 my with the bulk between 40 and 70 my, or latest Cretaceons to Eocene (Bally et al., 1980). Volcanic rocks are associated with the granites, particularly in the western Transhimalayas, and lie unconformably on Lower Cretaceous sedimentary rocks.

The plutons are similar in composition to 'I type' (White and Chappel, 1978) calc–alkaline plutons of magmatic arcs, and can most easily be explained as the root zone of a volcanic are developed during northward subduction of Tethys before Eocene collision of India with Asia along the Indus–Tsangpo suture. The location of the plutons, locally in contact with ophiolitic rocks of the suture, differs from that of active volcanic arcs which lie at least 80 km from the subduction zone. This indicates that most of the 80 km or more wide belt between the original trench and the magmatic arc in the Transhimalayas has been removed, presumably by underthrusting beneath Tibet.

There are a few reports of porphyry copper deposits associated with the Transhimalayan plutons, but no published descriptions are available.

Granitic ring complexes of southern Tibet

North of the calc-alkaline granodiotiritic plutons referred to above, a number of ring structures with associated granitic intrusions have been reported. These granites and associated acid volcanic rocks yield Tertiary K/Ar ages, and it is possible that they are post-collision granites related to very high heat flow in tectonically thickened crust beneath the Tibetan Plateau (K. Burke, pers. comm. 1980). Alternatively, the K/Ar ages could be interpreted as the result of a Tertiary heating event effecting older intrusions which possibly were generated during northward migration of the precollision volcanic arc described in the preceeding section.

No reports of mineralization are known from these granites, probably due to lack of exploration and absence of published information; if they are calc-alkaline subduction-related rocks it is probable that porphyry Cu-Mo deposits are present and possibly Kuroko-type stratiform Zn-Pb-Cu ores in volcanic rocks associated with the plutons; on the other hand if the plutons are post-collision and possibly rift-related granites, Sn, U, porphyry molybdenum and minerals associated with carbonatites could be expected.

CONCLUSIONS

Anatectic 'S type' granites in the Himalayas occupy distinct belts of mid-Tertiary, late Cambrian and possibly pre-Cambrian age. The late Cambrian plutons indicate an orogenic event and were emplaced either in a back-arc magmatic belt or foreland thrust belt, depending on the late Cambrian subduction direction.

The late Cambrian plutons have a very limited potential for tin and tungsten while the mid-Tertiary collision-related granites have some potential for tin, tungsten and uranium. The most favourable granitic rocks for copper mineralization are the late Mesozoic to Eocene 'I-type' granodiorites of the Transhimalayas.

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