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Some new observations on the Amritpur Granite Series, Kumaun Lesser Himalaya, India

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The Precambrian Amritpur Granite Series (AGS) in the Kumaun Lesser Himalaya is a composite body of three distinct types, viz. Porphyritic Amritpur Granite (PAG), Equigranular Amritpur Granite (EAG) Amritpur Porphyry (AP) and extends for a length of 60 km. Signature of Precambrian, pre-Himalayan contact metamorphism in addition to the Himalayan regional metamorphism (greenschist to lower amphibolite facies) and subsequent retrograde metamorphism are observed in the AGS. The authors have provided definite evidence for a contact aureole zone around AGS in the east of Hairakhan, NE of Durgapipal and Chandadevi and reported the xenoliths of PAG and EAG types in AP at Jamrani indicating a younger age of AP.

THE Amritpur Granite Series (AGS) is intrusive into the Bhimtal-Bhowali Formation (quartzite-metabasic association) and occurs in juxtaposition with the Siwaliks along the Main Boundary thrust (MBT), in the outer Kumaun Lesser Himalaya. The AGS is divisible into Porphyritic Amritpur Granite (PAG), Equigranular Amritpur Granite (EAG) and Amritpur Porphyry (AP¹, Figure 1a). These three types are well exposed along the Gola river section (Figure 1b). A lithotectonic set up of the area is presented in Table 1.

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PAG has unassimilated to assimilated xenoliths of metavolcanics and quartzites (Figure 2a). The assimilation of metabasic xenoliths in PAG has imparted a pink colouration to the K-feldspars (Figure 2b). The metabasic xenoliths have provided necessary Mg and Fe which under the influence of Himalayan orogeny have been redistributed (because of fluids during deformation and metamorphism). The xenoliths of PAG and EAG are present in AP, indicating that the origin of AP was later than PAG and EAG (Figure 2c).

The PAG has large phenocrysts of microcline/microcline microperthite (triclinicity varies from 0.604 to 0.833)² in the groundmass of subidiomorphic quartz, K-feldspar, microcline perthite, plagioclase, micas (biotite > muscovite), chlorite with zircon, apatite, tourmaline, sphene and monazite as accessory phases. The EAG shows hypidiomorphic (granitic) texture. It has quartz, K-feldspar, perthite, plagioclase with mica (muscovite > biotite), chlorite and tourmaline with the accessory phases (zircon, apatite, sphene and leucoxene). The AP has embayed grains of quartz and feldspar (plagioclase > K-feldspar) in the groundmass of quartz, K-feldspar, plagioclase, biotite, chlorite, penninite,

Table 1. The generalized litho-tectonic set up of the area (modified after Nautiyal and Rawat¹¹)

.....Ramgarh Thrust	
	Metabasic intrusives (dolerite) with sulphides near Saleri slates (grey, red and purple coloured)
Bhimtal-Bhowali Formation	Metabasics (metavolcanics), Coarse grained to fine grained (amygdaloidal) and foliated with sulphides (south of Bhimtal), Quartzites including thin lenses of hematite bearing quartzites and calc silicates
.....Intrusive contact	
Amritpur Granite Series	Metabasic intrusions (dolerites) with sulphides (south of Saleri), Tourmaline pegmatites, Aplite, Amritpur Porphyry (with Siwalik patch at Chaporiya) including sulphides (west of Jawari), Equigranular Amritpur Granite, Porphyritic Amritpur Granite
.....Intrusive contact	
Bhimtal-Bhowali Formation	Mylonitized quartzites, metabasics and slates with calc silicates and sulphides (in metabasics)
.....Main Boundary Thrust (MBT)	
Siwalik Group	Carbonaceous shales, clays and indurated pebbly grey to cream coloured sandstones with thin coal seams

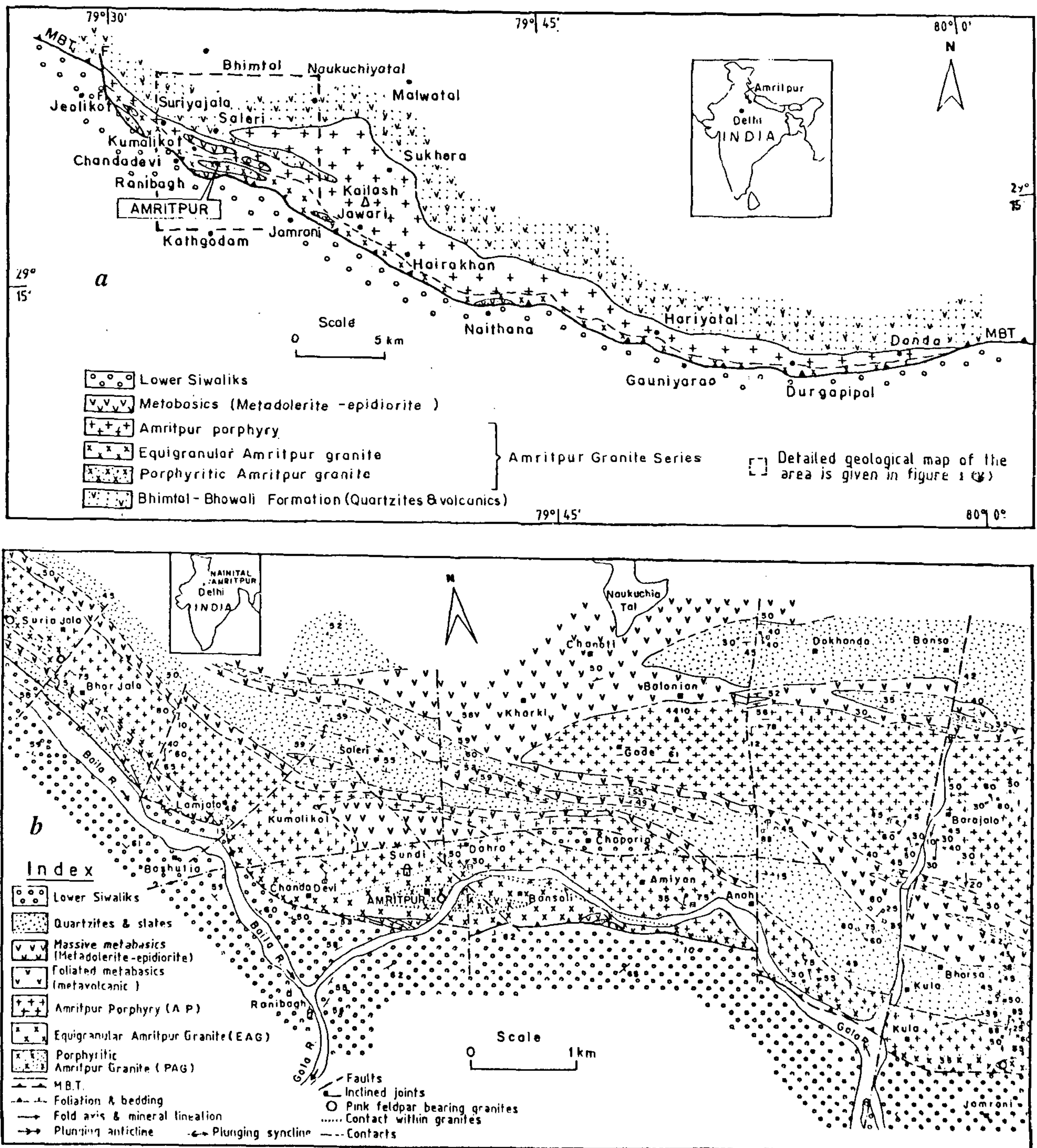


Figure 1. *a*, Geological map showing the extension of the Amritpur Granite Series⁶; *b*, Geological map showing the detailed geology of the area around Amritpur⁶.

aques, garnet and ilmenite. The quartz and feldspars show resorption phenomenon, indicating a fluid-rich environment³.

Structural state studies carried out by the authors have shown that the K-feldspar is intermediate to maximum microcline. There is an inversion of least ordered monoclinic K-phase (orthoclase) to the more ordered clinoclinal phase (intermediate to maximum microcline²).

The mineralogical assemblage of the AGS suggests the following metamorphic events in the area:

(a) Pre-Himalayan, Precambrian contact metamorphism produced by the AGS in the surrounding rocks evident by the presence of a thin (poorly preserved) contact aureole zone around AGS in Hairakhan, Durgapipal and North of Chandadevi. Diopsides

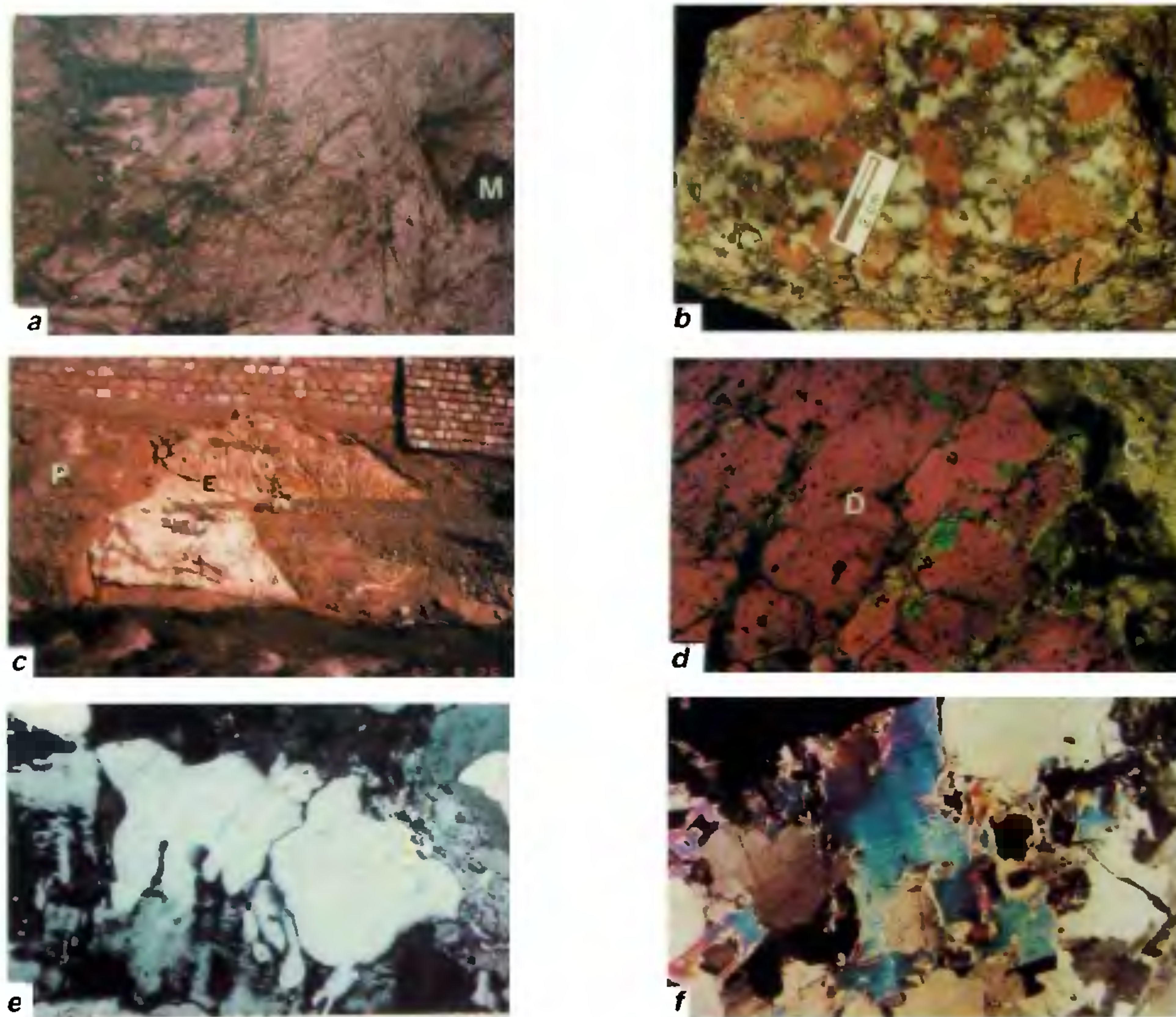


Figure 2. *a*, EAG with xenolith of metabasic rock (M) and quartzite (Q); *b*, PAG (pink) with well developed pink K-feldspar grains; *c*, Xenolith of EAG (E) within the AP (P); *d*, Photomicrograph showing deformed diopside (D) in the calc silicate rock (C); *e*, Graphic intergrowth of quartz and K-feldspar. Blebs of quartz are enclosed in K-feldspar; *f*, Photomicrograph showing phengite.

garnets are present in the adjacent impure calcareous sediments (quartzite, calcareous argillites) forming a thin zone of calc-silicate rock, (due to intrusion of AGS in the Bhimtal-Bhowali Formation⁴) which were later deformed during the Himalayan orogeny (Figure 2 *d*).

(b) The later regional metamorphic event (during Himalayan orogeny) caused the inversion of monoclinic alkali feldspar (orthoclase) to triclinic alkali feldspar (microcline), besides the development of vein perthites (secondary) and pink K-feldspars in the PAG⁵. Furthermore, there was development of micrographic intergrowths (Figure 2 *e*) between the quartz and feldspar, formation of rapakivi and rapakivi-like texture in the feldspars, together with the secondary twinning in plagioclase. The observed mineralogical assemblages of the AGS include the quartz + K-feldspar (microcline) + perthite + albite (An < 10%) + muscovite + biotite +

chlorite ± epidote + clinozoisite ± zoisite, in the case of EAG and PAG types and quartz + K-feldspar (microcline) + plagioclase (oligoclase-An < 25%) + biotite + garnet (alamandine) + muscovite + chlorite ± epidote ± clinozoisite ± zoisite + sphene ± sulphides in case of AP⁴. The two feldspar thermometry for the AGS further gave a temperature of $400 \pm 50^\circ\text{C}$ for the regional metamorphism with a tentative pressure of 4 K-bar⁶ of green schist to lower almandine amphibolite facies^{4,6}.

(c) There are evidences of retrogression of minerals after the main regional metamorphic episode under the Himalayan orogeny, during which the earlier formed stable minerals have re-equilibrated under the new environment. As a result of retrogression, the plagioclase was sericitized or retrograded to phengite (Figure 2 *f*), biotite was changed to chlorite and muscovite changed to phengite.

The AGS and the associated rock formations of the area were grouped in Deoban Group (Riphean age). These rock formations have also been correlated with the Chail metamorphics (part of Ramgarh/Chail Nappe). Earlier workers have also correlated the Bhimtal-Bhowali Formation with the Nagthat Formation (Mid Devonian) as it lies at the base of Krol Nappe. Now the age of Krols is considered to be quite older, indicating an older age for the Bhimtal-Bhowali Formation. Bhimtal-Bhowali volcanics have been assigned the age of 2.51 ± 0.08 Ga (ref. 7). Further, it is clear that the Bhimtal-Bhowali Formation in this area is either not equivalent to Nagthat or the age of Nagthat has not been properly worked out. So, it is not appropriate now to correlate the Bhimtal-Bhowali Formation with the Nagthat Formation (Mid Devonian).

The AGS have been dated as 1880 ± 40 Ma (refs 8, 9), although Varadarajan⁸ has also given a younger age of 1330 ± 80 Ma as the remobilization age of Amritpur Granite. The AGS is intrusive into the Bhimtal-Bhowali Formation which is indicated by the presence of xenoliths, lenses of metabasics, quartzites in the AGS and the contact aureole zone in the host rocks. This is further supported by the age (2.51 ± 0.08 Ga) of Bhimtal-Bhowali Formation.

A younger phase of mafic intrusion (dolerites, now epidiorites) is also present in the area (evident by xenoliths of the AGS in the dolerites) and it may be possible that the younger age given to the metabasics of this area, i.e. upper Permian by Valdiya¹⁰, might correspond to this younger phase.

The present study establishes the existence of PAG, EAG and AP throughout the AGS. The AGS bears signature of three types of metamorphism, i.e. Precambrian, pre-Himalayan contact metamorphism, superimposed by Himalayan regional metamorphism and subsequent retrograde metamorphism. Thus, it can be

summarized that the Bhimtal-Bhowali Formation is the oldest formation in the area (approx. 2.51 ± 0.08 Ga) followed by the intrusion of AGS rocks at 1880 ± 40 Ma. The intrusion of AGS followed the intrusion of aplites and tourmaline pegmatite. The mafic intrusion (doleritic, now epidiorites) are the youngest and may correspond to the age of Upper Permian. However, further geochronological data are still needed to understand the litho-tectonic implications properly, so that some light can be thrown on the relevance of AGS in juxtaposition to MBT to the northern margin of the Indian shield.

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