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Petrography of the Deosai volcanics, N. Pakistan

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ABSTRACT: *The western extension of the Dras volcanics in the Deosai plateau is made up of agglomerates and tuffs together with flows comprising basalt, andesite and some rhyolite. The flows appear to have evolved from a basaltic magma, with opaque oxide, clinopyroxene, hornblende and plagioclase, respectively appearing on the liquidus. These have been metamorphosed under greenschist facies conditions and may contain abundant epidote, chlorite and secondary amphibole. An $^{40}Ar/^{39}Ar$ age of 125.4 ± 6 Ma on hornblende phenocrysts in an andesite is in agreement with the Late Jurassic to Cretaceous age of the Dras volcanics.*

INTRODUCTION

The Deosai volcanics are a westerly extension of the Late Jurassic-Cretaceous Dras volcanics of the Ladakh island arc. The Dras volcanics have been studied in considerable detail by many workers (e.g., Raiverman and Misra, 1974; Shah et al., 1976; Gupta et al., 1983; Honegger, et al., 1982; Dietrich et al., 1983; Sharma, 1990). But apart from brief accounts based on field studies (Lydekker, 1883; Middlemiss, 1919; referred in Wadia, 1937; Desio, 1978) the Deosai volcanics have not been studied in any detail. In order to collect samples from the volcanics, one of us (SH) made reconnaissance traverses from Astor to Kalapani, Astor to Gul Tari and Minimarg via Chilum and Burzil Pass, and Chilum to Skardu via Bara Deosai and Satpora river.

PETROGRAPHY

The Deosai plateau is apparently occupied by plutonic rocks of the Ladakh batholith with a cover sequence of volcanic rocks. Much of the plateau is now covered by Quaternary glacio-fluvial and alluvial deposits.

Granitic rocks of the Ladakh batholilts, a volcanic series, and sedimentary rocks from the south western part of the Deosai plateau and adjacent Kishanganga vally were mapped and briefly described by Wadia (1937). The complexly folded and some 20km broad volcanic belt, presumably occupying a synclinal flexure, was shown to extend NW to SE towards Dras. Wadia (1937) noted that the volcanic series cosists of a sequence of well stratified ash beds with some siliceous bands, gritty silliceous tuffs, slates (some agglomeratic), agglomerates and volcanic flows. The ash beds and agglomerates are each several hundred meters thick and the volcanic series contain intercalated sediments of Cretaceous age (Orbitolina limestone) and scattered masses of ultramafic, mafic and granitic rocks. The volcanic belt is shown to be boardered on its south by the Salkhala series and on its north by the Ladakh batholith. In the following we present petrographic data on the samples collected from the volcanic flows and neglect the rest of the rocks.

The volcanic flows are generally altered or metamorphosed in greenschist facies and bulk chemical analyses are not available. For these reasons, it is hard to precisely classify them although the presence of andesite was mentioned by Desio (1978). In some rocks the abundance of ferromagnesian minerals suggests basaltic chemistry, in others the abundance and composition of plagioclase point to andesitic nature. In Dras area, however, basalts are much more abundant than andesites (Gupta et al., 1983; Honegger et al., 1982; Sharma, 1991). For these reasons, we use a sack name andesitic basalt for the Deosai volcanics, but some porphyritic rhyolite occurs in Minimarg-Kalapani section. In this section and Bara Deosai, both porphyritic and aphyric andesitic basalts occur, whereas in Chota Deosai and Chilum-Burzil areas they are apparently aphyric, at least megascopically.

Aphyric Andesitic Basalt

These display considerable modal variations

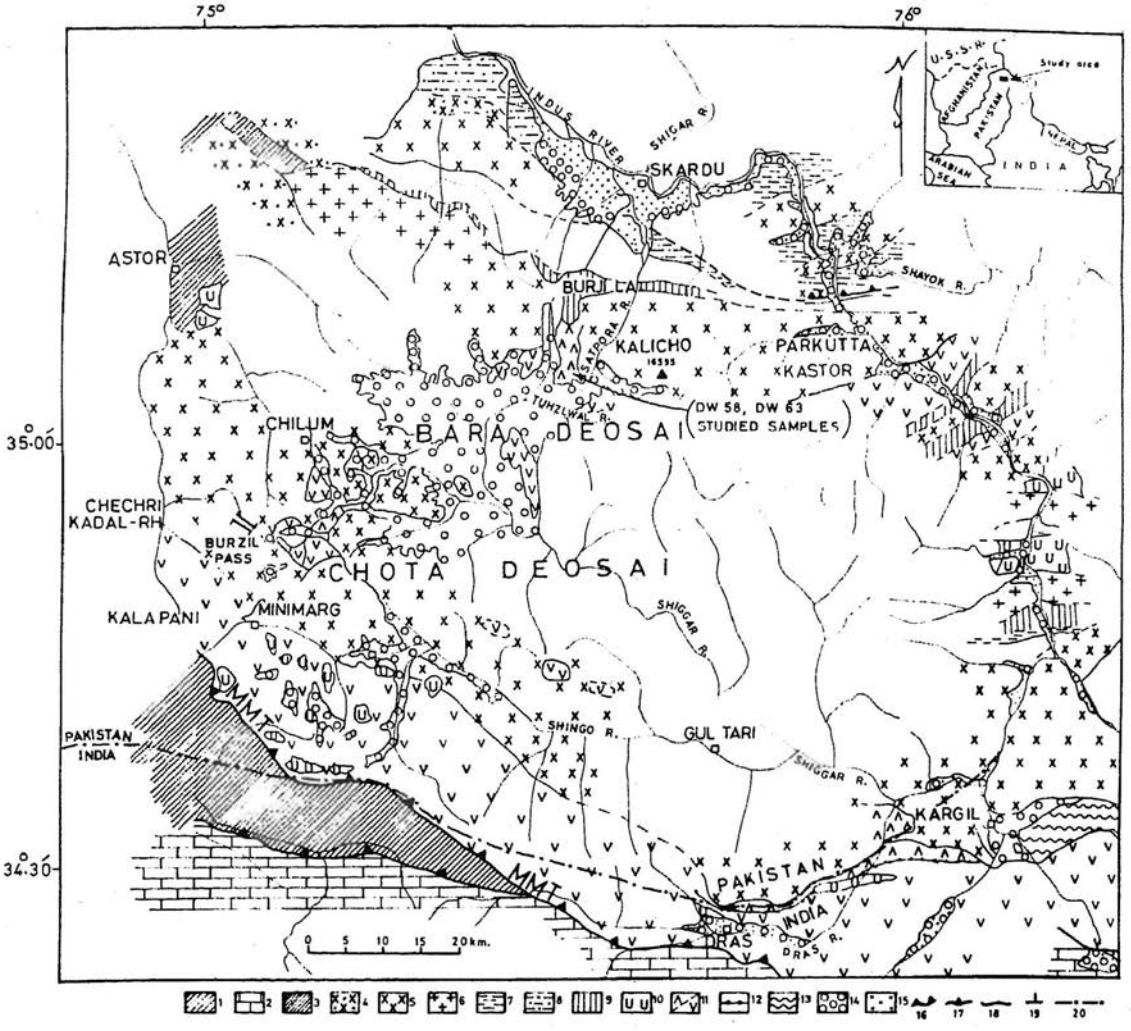

Fig. 1. Geological map of the Deosai plateau and surrounding areas, Baltistan, N. Pakistan (modified after Desio, 1978). Volcanic outcrops along the north-eastern bank of Shingo river and between Minimarg and Kalapani are added during the present work. Legend: 1.Salkhala Formation, 2. Upper Triassic limestone, 3. Burji Formation, 4. Diorite, 5. Deosai quartz diorite and granodiorite with epidiorite inclusions, 6. Granite, 7. Gneiss, 8. Katzarah schists, 9. Hornfels, 10. Mafic & ultramafic rocks, 11. Dras volcanics, 12. "Conulites" (?) limestone, 13. Wakka Formation, 14. Glacial and fluvio-glacial deposits, 15. Alluvial deposits, 16. Overthrust, 17. Fault, 18. Limit of the formations, 19. Dip of beds, 20. International boundary.

due to alteration and low grade metamorphism. The rocks are made up of plagioclase, chlorite, epidote and opaque oxide, with or without quartz, carbonate and rarely phyrite. In the least altered rocks, glass also occurs. The plagioclase may be cloudy, sericitized or replaced by epidote, whereas the opaque oxide (in some skeletal) may be converted to leucoxene. Amygdules may be made up of carbonate or radiating plagioclase grains surrounded by epidote. In Chota Deosai, some samples contain pools of epidote surrounded by chlorite. Samples from the Minimerg-Kalapani section also contain a bluish green hornblende and a late grown acicular actinolite cutting plagioclase and epidote. The rocks contain thin veins of epidote ± carbonate, but some veins in Chota Deosai contain garnet in association with chlorite and epidote.

Samples from the Chilum-Burzil section contain plagioclase, hornblende, clinopyroxene, epidote and chlorite (both secondary), and opaque granules (in some abundant). The plagioclase (andesine, partially sericitized) forms slender prisms (< 1 mm) which may show flow alignment. The hornblende (bluish green and olive green types) and clinopyroxene are altered to varying degrees to epidote and chlorite, and ilmenite to leucoxene. Some acicular actinolite cross cuts the plagioclase and chlorite. Amygdules are made of carbonate and there are thin veins of epidote, garnet and plagioclase.

Porphyritic rhyolite

A rhyolite sample was collected from the volcanic rocks near the contact with the Ladakh batholith at Minimarg. It is a fresh rock containing large phenocrysts ($\leq$0.5mm) of quartz and K-feldspar in a fine-grained groundmass of quartz, feldspar and opaque ore.

Porphyritic andesitic basalt

In the upper reaches of Satpora river, three types of volcanic rocks can be distinguished on the basis of phenocryst population: A) pyroxene-hornblende-, B) plagioclase-, C) pyroxene-plagioclase phyric. The latter type also occurs near Kalapani. In type A, pyroxene and hornblende phenocrysts, up to 0.5 mm in length and making a third of the total volume, lie in a fine-grained matrix of plagioclase (some sericitized), hornblende, biotite, and opaque ore. The phenocrysts are anhedral to subhedral. They display reaction rims and are locally corroded on margins. The hornblende grains, containing rare pyroxene cores, may be shattered, with the groundmass occupying the fractures. The clinopyroxene phenocrysts are strongly zoned, fractured, and contain magnetite inclusions. Some pyroxene grains are completely altered to serpentine/talc + mag-

TABLE 1. AVERAGE CLINOPYROXENE AND HORNBLENDE FROM THE PORPHYRITIC ANDESITIC BASALT OF BARA DEOSAI.

	Cpx (70 spots)	Hbl (85 spots)	Cpx	(6 oxygens)	Hbl (23 oxygens)
SiO_2	48.48	40.85	Si	1.840	5.909
TiO_2	0.65	2.02	Ti	0.019	0.220
Al_2O_3	4.34	13.25	^{iv}Al	0.160	2.091
Fe_2O_3	3.32	8.22	^{vi}Al	0.034	0.169
FeO	4.89	4.87	Fe^{3+}	0.095	0.895
MnO	0.13	0.10	Fe^{2+}	0.160	0.589
MgO	14.11	14.37	Mn	0.004	0.012
CaO	21.91	12.17	Mg	0.800	3.089
Na_2O	0.37	2.66	Ca	0.891	1.886
K_2O	0.00	0.27	Na	0.027	0.746
Cr_2O_3	0.70	0.16	K	0.000	0.050
Total	98.92	98.94	Cr^{3+}	0.002	0.018

Fe_2O_3:FeO determined on 4 cation in clinopyroxene and 13 cations, excluding Ca, Na and K, in hornblende (see Papike et al., 1974)

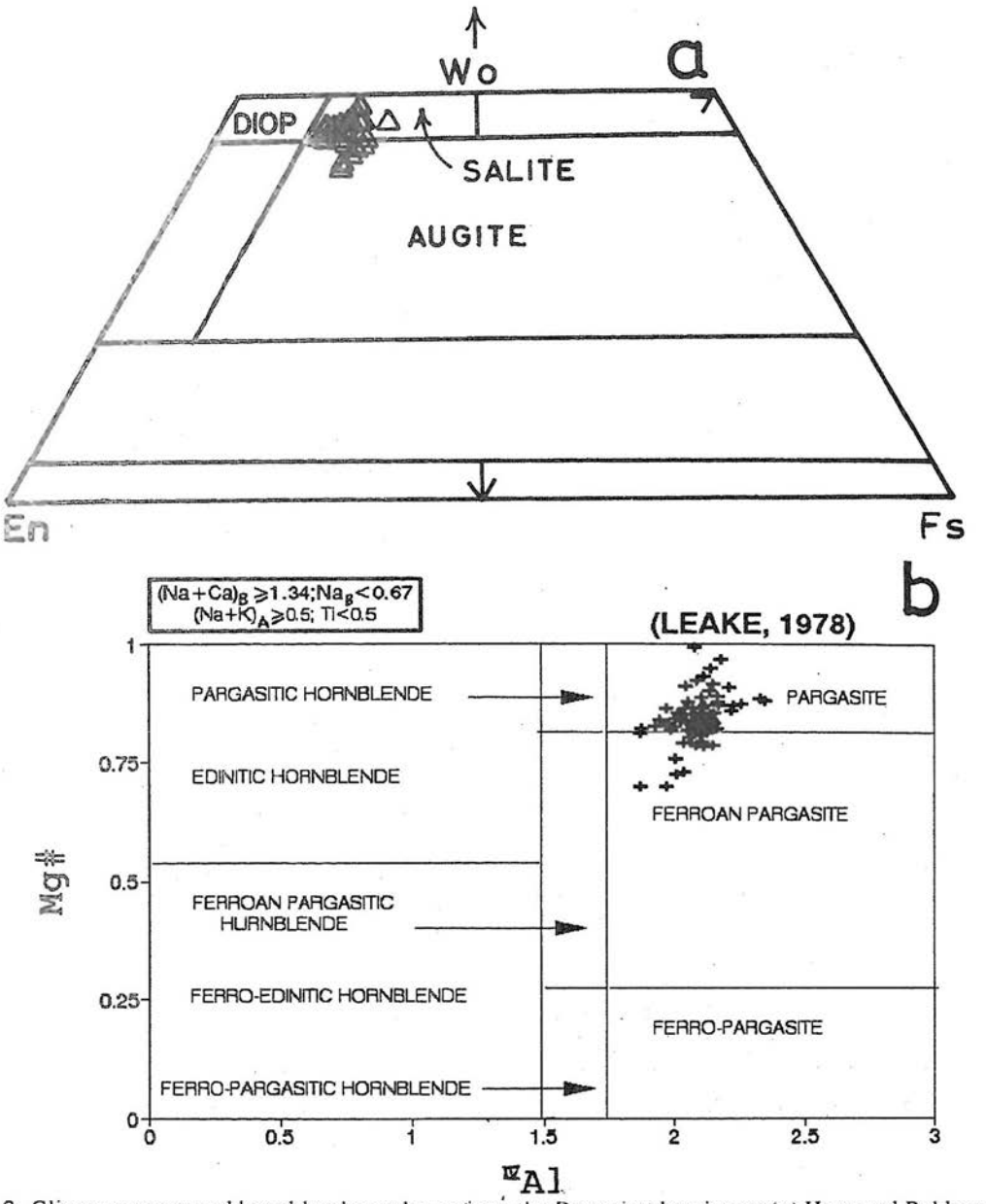

Fig. 2. Clinopyroxene and hornblende analyses from the Deosai volcanics on (a) Hess and Poldervaart (1951) quadrilateral and (b) Mg# vs Si plot of Leake (1978), respectively.

netite. Microprobe data suggest that the hornblende is pargasite, whereas the clinopyroxene phenocrysts range from calcic augite to salite (Table 1, Fig.2).

The plagioclase-phyric andesite contains phenocrysts of zoned and turbid plagioclase in a brown-stained (Fe-leached) groundmass of plagioclase, opaque ore, chlorite, epidote, ± Sphene ± quartz. Some samples contain large crystals of fresh, recrystallized plagioclase, but one sample contains fresh phenocrysts of plagioclase with euhedral opaque inclusions in a glassy matrix. At least some of the type B andesites appear to be agglomeratic. In the type C andesites, the phenocrysts of clinopyroxene and zoned plagioclase (1-3mm) lie in a fine-grained matrix of amphibole (in some

bluish green), opaque ore and clinopyroxene, with or without chlorite, sphene and epidote. The plagioclase phenocrysts are commonly turbid, locally epidotized or gone over to sericite and carbonate, and in some cases resorbed on margins. Along Satpora river the pyroxene is largely altered to magnetite and serpentine/talc, but in Kalapani it is converted to blue-green amphibole which may also grow along the margins and fractures of plagioclase. Amygdules in one sample are filled with radiating plagioclase which is surrounded by epidote. Textural variations and alteration are common in Chilum-Burzil section and some of the rocks resemble microdiorite.

DISCUSSION

The Deosai volcanics consist mainly of ash beds, agglomerates and flows. The latter appear to range in composition from basalt to andesite with local rhyolite. Metamorphism in greenschist facies, followed by alteration, led to common development of secondary amphibole, epidote, chlorite, new plagioclase, sericite, leucoxene, and obliteration of volcanic texture in several samples. Metamorphism seems to be regional but the presence of hornfelsic texture in some samples suggests that the Ladakh batholith may also have played some role in locally providing thermal energy.

The altered nature and lack of chemical data do not allow to decipher the compositional affinity of the Deosai volcanics. However, detailed investigations of the neighbouring Dras volcanics, which are an extension of those of Deosai, show that they have island arc-related tholeiitic to calc-alkaline characteristics (Honegger et al., 1982; Sharma, 1990; and other references therein). We assume that the Deosai volcanics are derived from a basaltic liquid with opaque oxide, clinopyroxene, hornblende and plagioclase, respectively, on the liquidus. Corrosion/reaction rims on the margins of the clinopyroxene and hornblende phenocrysts and zoned plagioclase with resorbed margins suggest variation in pressure, temperature or magma composition during their evolution (Hamidullah, 1991).

$^{40}Ar/^{39}Ar$ determination on hornblende phenocrysts from andesite DW58, near the upper reaches of Satpora river, gives an age of 125.4 $\pm$ 6 Ma. This age falls in the upper Jurassic to upper Cretaceous age of the Deosai and Dras volcanics established by faunal and radiometric means (Wadia, 1937; Frank et al., 1977; Dietrich et al., 1983; Sharma, 1991).

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