# Petrography and geochemistry of Khewra Trap, a unique ultrapotassic rock in the Salt Range of Pakistan

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The Salt Range (72°W, 32.5°N) has long been considered as a classical area for stratigraphic studies. It displays a nearly complete section of fossiliferous sedimentary rocks ranging from Early Permian to Pleistocene, which rest unconformably over Middle (to Early?) Cambrian and Eocambrian rocks. Khewra trap (KT), the product of the only igneous activity in the entire Salt Range, occurs as thin sheets in the upper part of the evaporites of the Salt Range Formation. Since first reporting in1853 [1], the KT has attracted the attention of several geologists because of its unusual texture and unique composition, however, this is the first detailed account of its geochemistry.
The KT is a very fine-grained porphyritic and amygdaloidal rock with typical spinifex texture. It displays red, purple, brown, buff, commonly mottled, colours which can be related to the degree of alteration and leaching of iron oxide. However, less altered greenish trap occurs in a few places. The trap is generally considered as volcanic and erupted in lacustrine environment, but an intrusive origin has also been suggested by a few. The KT contains abundant phenocrysts (up to 25 vol%), commonly acicular and reaching up to 4 cm in length (Fig. 1). They range from euhedral to skeletal (rarely feathery) and incorporate inclusions of the matrix. All the phenocrysts (probably enstatite, but possibly also some olivine) are completely replaced by talc, with subordinate amount of saponite, hectorite, local quartz and rare (?) dolomite. Titano-magnetite microphenocrysts occur only sparingly. The matrix is micro- to cryptocrystalline, locally glassy (?), and essentially of K-feldspar composition with granules of secondary hematite and magnetite. The normative composition of the analysed samples suggests that it is essentially made up of orthoclase and enstatite.

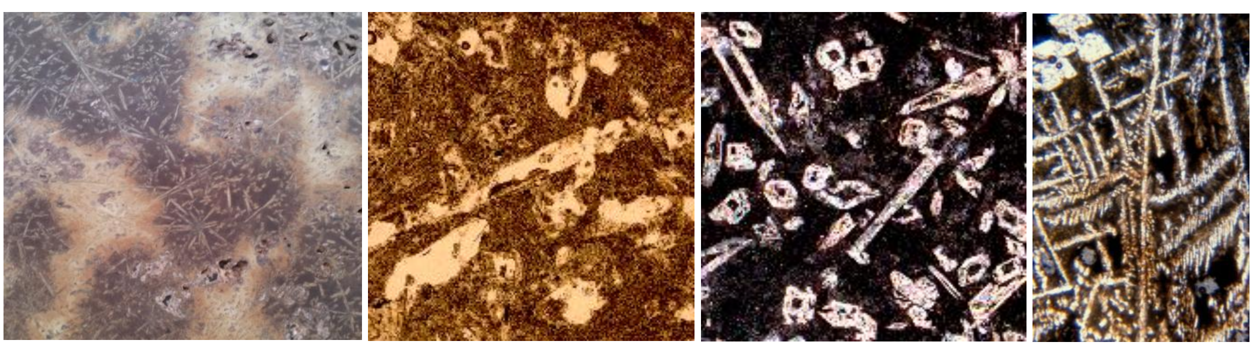

Fig. 1. L to R: 1. Slab of altered KT showing acicular phenocrysts in fine-grained matrix. Length of phenocryst in the upper left is 4 cm. Cavities have secondary linings. Areas from where Fe oxide has been leached out are lighter in colour. 2-4. Photomicrographs showng typical spinifex texture. Phenocrysts contain inclusions of the matrix, and are completely altered to talc and Mg-rich clays. The matrix comprises micro-/cryptocrystalline orthoclase/sanidine and iron oxide/hydroxide dust. No 2 is in plane light, 3 and 4 are under crossed polars. Length of pictures 2 and 4 is 2.3 mm and that of 3 is 4.6 mm.

Analyses of 12 samples are very similar in major, trace and RE elements. They are characterized by high MgO (9-11 wt%), $K_2O$ (9-10%), and low CaO (<0.5%), $Na_2O$ ( <0.6%, except in three with 0.8-1.1%), MnO (<0,02%), $P_2O_5$ (0.04-0.10) , Cr (38-65 ppm) and Ni (34-53 ppm). Some variation is seen in total $Fe_2O_3$ and $SiO_2$, possibly due to alteration. They are enriched in LIL and RE elements, and their mantle and chondrite normalized spidergrams display Ba, Th-K, La-Ce, Nd, Zr, Tb peaks and Nb, Sr, P, Ti, Eu troughs. Primitive-mantle normalized spidergram of the KT were compared withvolcanic rocks from different tectonic settingsd There is close similarity in the patterns of the spidergrams of the KT analyses and the Santorini lava of the Aegean island arc.

The major elements group the KT with continental ultrapotassic (lamproitic) rocks, but its trace elements share the characters of subduction-related rocks, especially ultrapotassic ones, as well as lamproites. The Mg# of the analyses is high (0.6-0.8), but in the least altered rock with the highest amount of total $Fe_2O_3$, it is 0.57, suggesting leaching away of Fe as the likely cause for the high mg#. Coupled with the low Cr and Ni contents, it negates derivation from a primary magma. It is suggested that the KT evolved through fractionation of plagioclase, apatite, titano-magnetite, enstatite and, possibly, olivine.

The high K/Ba, K/Rb, Zr/Nb and Mg#, and low Ca, Na, Sr, and P in the KT do not favour crustal contamination [2] despite the presence of small amounts of normative corundum and the rather high $SiO_2$, Rb/Sr, and LILE content. The Salt Range evaporites and KT are associated closely in space and time, and it is tempting to relate them to rifting. However, the geochemical characteristics of the KT are distinctly different from rift-related ultrapotassic rocks. The major oxide analogy of the KT with lamproites leads to propose that the KT magma may have originated in the upper mantle underlying stable continental interior. Similarity of KT with the subduction-related magmas may suggest recycling of ancient continental crust in the mantle. But the low Na/Ba, Sr/Nd and high Rb/Sr, K/Na, and K/Ti are suggestive of phlogopite in the source region. The parent magma may have been produced by partial melting of an enriched (phlogopite-bearing) mantle which had undergone melt extraction before metasomatism.

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Key words: ultrapotassic rocks, geochemistry, Salt Range, Pakistan