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Field relations and structural constraints for the Teru volcanic formation, northern Kohistan Terrane, Pakistani Himalayas

S. Danishwar[a,*], R.J. Stern[a], M.A. Khan[b]

[a]Department of Geosciences, University of Texas at Dallas, Richardson, TX 75083-0688, USA
[b]National Center of Excellence in Geology, University of Peshawar, Pakistan

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Abstract

The products of Late Cretaceous–Paleogene Andean style magmatism along the southern margin of Asia are preserved in the 2500 km long Trans-Himalayan (Kohistan–Ladakh–Gangdese) granitoid batholith, together with scattered volcanic outcrops (basalts, andesites, rhyolites and pyroclastics). Andean–type magmatism began in northern Pakistan as early as Late Cretaceous and lasted until terminal collision with India at about 45 Ma. We present new field and structural data for the Teru volcanic formation (previously known as the Shamran volcanics) exposed west of Gilgit in the Kohistan terrane of the Pakistani Himalayas. The Teru volcanic formation comprises a 3-km thick sequence of subaerially-erupted mafic to felsic lavas and associated volcaniclastic rocks. The Kohistan batholith bounds this sequence to the south and the sequence is overthrust to the north by the mid-Cretaceous Chalt volcanic group (intra-oceanic arc phase) along the south-verging Ghizer thrust. These volcanics are lithologically comparable to similar-age suites elsewhere in the Himalayas. This suggests that the paleogeography of southern Asia at this time was dominated by an extensive convergent-margin province prior to collision with India. After India collided with Asia, the Kohistan terrane was uplifted and eroded, which removed most of the Andean margin phase volcanics. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Continental arc magmatism; Kohistan terrane; Pakistani Himalayas

1. Introduction

Processes of mountain-building that formed the Himalayas began during Cretaceous time, when India started drifting northward (Molnar and Tapponier, 1975; Scotese et al., 1988). At that time, the intra-oceanic Kohistan–Ladakh arc formed over a subduction zone, which dipped beneath it either to the south or to the north (Khan et al., 1997). Earlier investigators preferred the interpretation that the dip was to the north (Pudsey, 1986; Petterson and Windley, 1985; Robertson and Degnan, 1994). However, Khan et al. (1997); Searle et al. (1999) inferred a south dipping subduction zone [Fig. 1(a)]. The drifting of India was coeval with the accretion of an intra-oceanic arc system—the Kohistan–Dras arc—that collided with Asia along the Shyok suture sometime between 75 and 95 M ago [Fig. 1(b)]. However, Clift et al. (2000) put the India–Asia collision age at <75 Ma in Ladakh. The southern margin of Asia, including Kohistan–Ladakh, then became an Andean-type convergent margin, which lasted for 30–50 million years, until India collided with Asia [Fig. 1(c)]. The products of the Late Cretaceous–Paleogene Andean-type margin magmatism along the southern margin of Asia are preserved in the 2500-km long Trans-Himalayan (Kohistan–Ladakh–Gangdese) granitoid batholith and outcrops of volcanic rocks (basalts, andesites, rhyolites and pyroclastics; Fig. 2). This phase began in northern Pakistan during late Cretaceous time and lasted until terminal India–Asia collision at about 45 Ma (Petterson and Windley, 1985).

Plutonic rocks are now the dominant representatives of the Andean margin phase in outcrop. Moreover, a dense network of late-stage, post-collisional granitoids intruded the Andean margin phase plutons, volcanic rocks and their country rocks. These Miocene and younger leucogranites make up about 30% of the exposures in the Gilgit area (Petterson and Windley, 1985), obscuring earlier phases of igneous activity. The volcanic rocks erupted during the Andean margin phase are rare and exposed in remote areas of high relief, reflecting extensive erosion after India collided with Kohistan. All these factors have hindered the study of this phase of Himalayan evolution.

Representations of the Andean margin phase in Kohistan

* Corresponding author. Tel.: +1-972-883-2401; fax: +1-972-883-2537.
E-mail address: shuhab@utdallas.edu (S. Danishwar).

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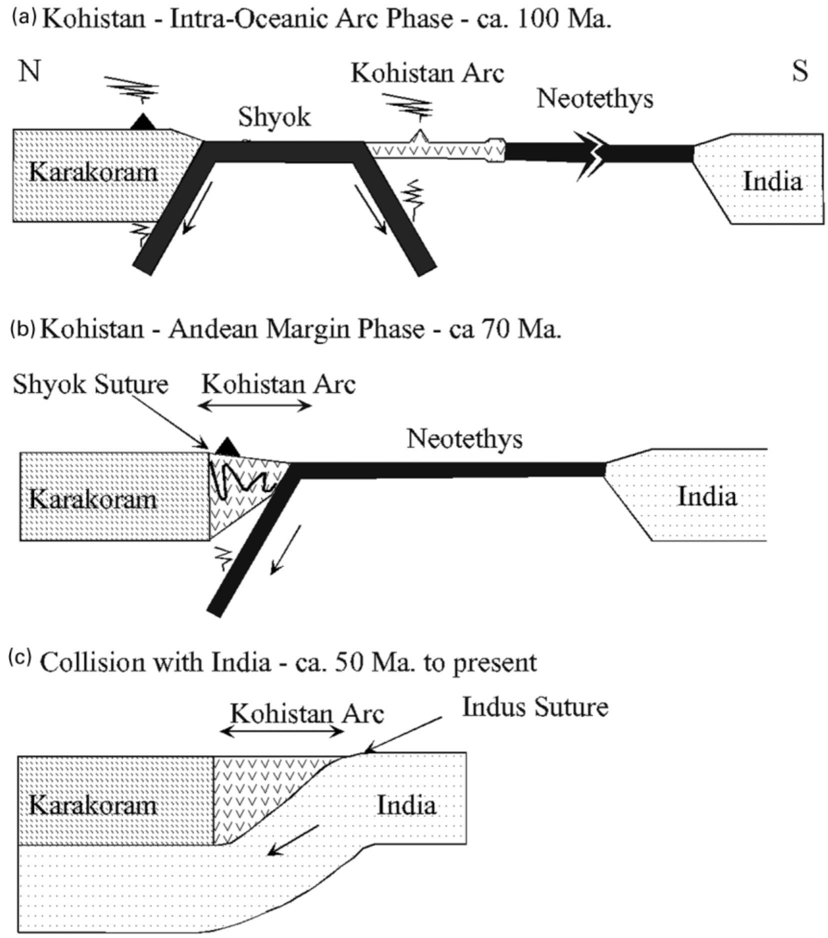

Fig. 1. Tectonic model for the evolution of NW Himalayas (modified after Khan et al., 1997; Searle et al., 1999).

are found in three places (see Fig. 3). The Utror volcanics are exposed in the south, (Tahirkheli and Jan, 1979), comprising 3000 m of volcaniclastic sediments, lava flows and ignimbrites (Sullivan et al., 1993). The lava flows consist of a variably altered suite of tholeiitic and calc-alkaline lavas, ranging from basaltic andesite (53% SiO_2) to high-silica rhyolite (79% SiO_2), with a bimodal distribution of andesite and rhyolite (Sullivan et al., 1993). Based on detailed geochemical and field studies, Shah and Shervais (1999); Sullivan et al. (1993) concluded that the Utror volcanics formed in a subaerial environment associated with the Andean margin phase. Treloar et al. (1989) reported a $^{40}Ar/^{39}Ar$ hornblende age of 55 ± 2 Ma for the Utror volcanics. This is consistent with a late Paleocene fauna identified in limestone within the Baraul Banda Slates (Khan, 1979). The second representative of Andean margin phase igneous activity is the Kohistan batholith. This is a composite batholith that includes intrusions emplaced during the Andean margin phase and a subordinate, earlier portion that was emplaced during the intra-oceanic phase (Petterson and Windley, 1985). The third and northernmost representative of the Andean margin phase in Kohistan is the Teru volcanic formation (previously known as the Shamran volcanics), which are the focus of the present study. The presumably correlative Teru volcanic formation in northern Kohistan and the Utror volcanics in southern Kohistan indicate extensive volcanic activity. Understanding these volcanic rocks and their relationship with other Andean margin phase igneous suites is important for reconstructing the Early Tertiary history of Kohistan and the Himalayas.

Field studies were carried out in the Teru–Shandur area in northern Kohistan terrane of the Pakistani Himalayas during summers of 1997 and 1998. These studies identified a representative section of unmetamorphosed lavas and volcaniclastic sediments of the Andean margin phase for the first time in this part of the Himalayas. This paper describes the field relations, stratigraphy and structure of the Teru volcanic formation and provides a basis for geochemical and isotopic studies that will be reported later.

2. Methodology

Two landsat multi spectral scanner (MSS) scenes over northern Pakistan were mosaiced, printed at 1: 100,000 scale, and used as base maps in the field (Fig. 4). USGS 30-arc second digital elevation model (DEM) was draped over the MSS scenes to obtain a three-dimensional (3-D)

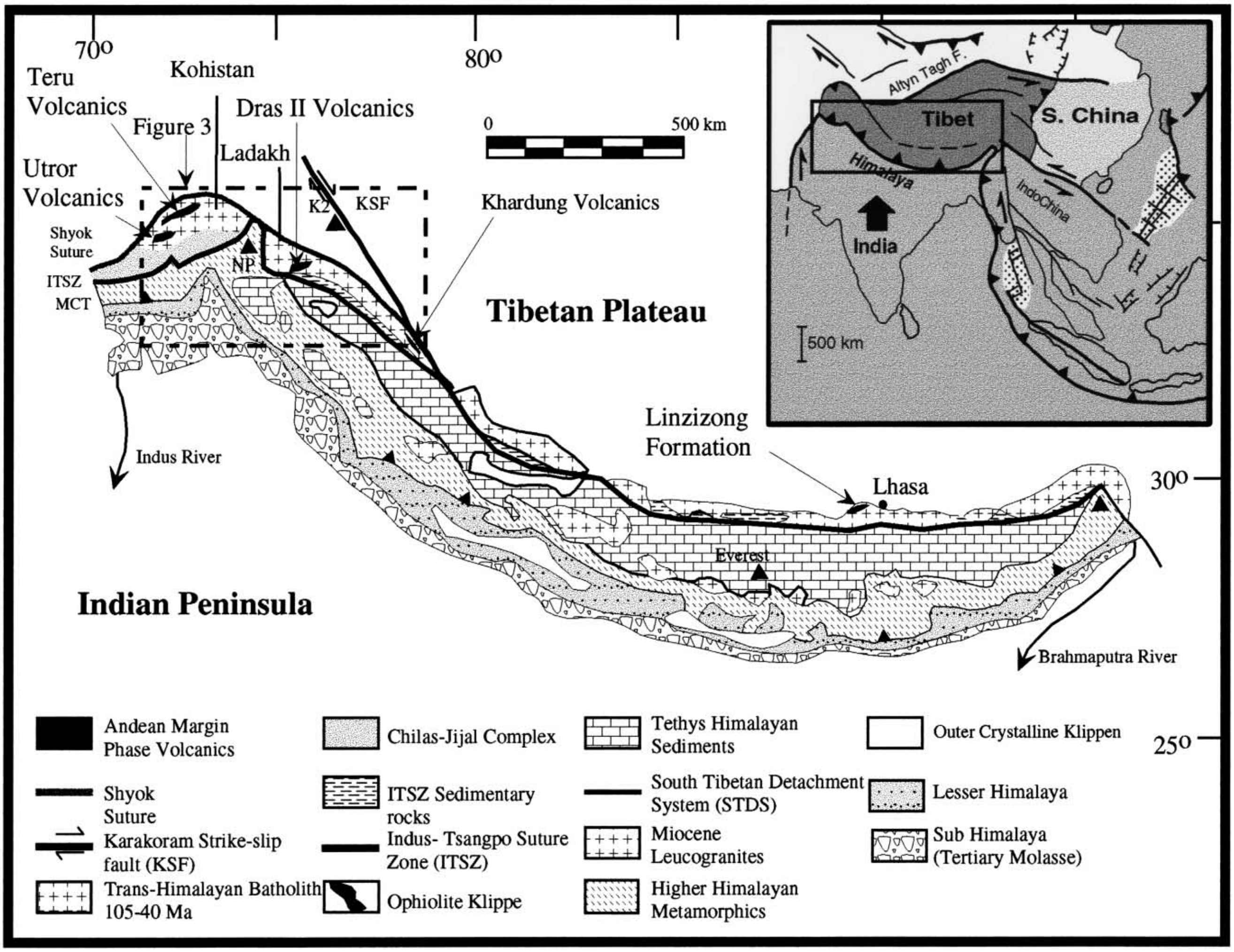

Fig. 2. General geological map of the Himalayas showing Andean margin phase volcanism (modified from Ganseer, 1981; Harrison et al., 1992; Sharma, 1991; Sorkhabi and Macfarlane, 1999; Windley, 1983).

model. This 3-D model was useful in selecting locations for detailed mapping and measurement of section. In the field, a Trimble global positioning system (GPS) receiver was used to determine sample and data locations. GPS readings were also taken near important topographic features such as the confluence of rivers, peaks, etc., which were used as ground control points. GPS locations are accurate to ± 100 m. This data was used for geo-referencing the maps and landsat thematic mapper scene.

The section discussed here was measured near Teru village, because the contacts are well exposed and accessible. The section was measured using the pace and compass technique which was useful because the volcanic rocks have very low dips.

3. Previous work

Early workers did not distinguish among the volcanic sequences in this part of Kohistan. Hayden (1914) was the first to report volcanic rocks in the Gilgit–Chitral area. Ivanac et al. (1956) referred to the volcanic rocks around and west of Gilgit as a single greenstone complex. Desio (1963), working in the western Karakoram, included all the volcanics in this area in the Turmik formation. Matsushita and Huzita (1965) called the volcanic rocks a ‘green series’. Desio et al. (1977) worked on Cretaceous outcrops in the Laspur valley and surroundings and produced a generalized map, which showed porphyritic volcanic rocks without giving any name. Tahirkheli (1982) referred to the volcanic rocks as the Rakaposhi volcanic group. Pudsey et al. (1985a) was the first to use the term Shamran volcanics, after a nearby village, for all the volcanic, volcaniclastic and sedimentary rocks in the Shandur–Shamran area, including the Cretaceous sequence now known as the Chalt volcanic group. Sullivan et al. (1993); Treloar et al. (1996) first differentiated the older, metamorphosed, and deformed Chalt volcanic group from the undeformed, unmetamorphosed volcanics found as boulders west of Gilgit and named the latter the Shamran volcanics. The present study

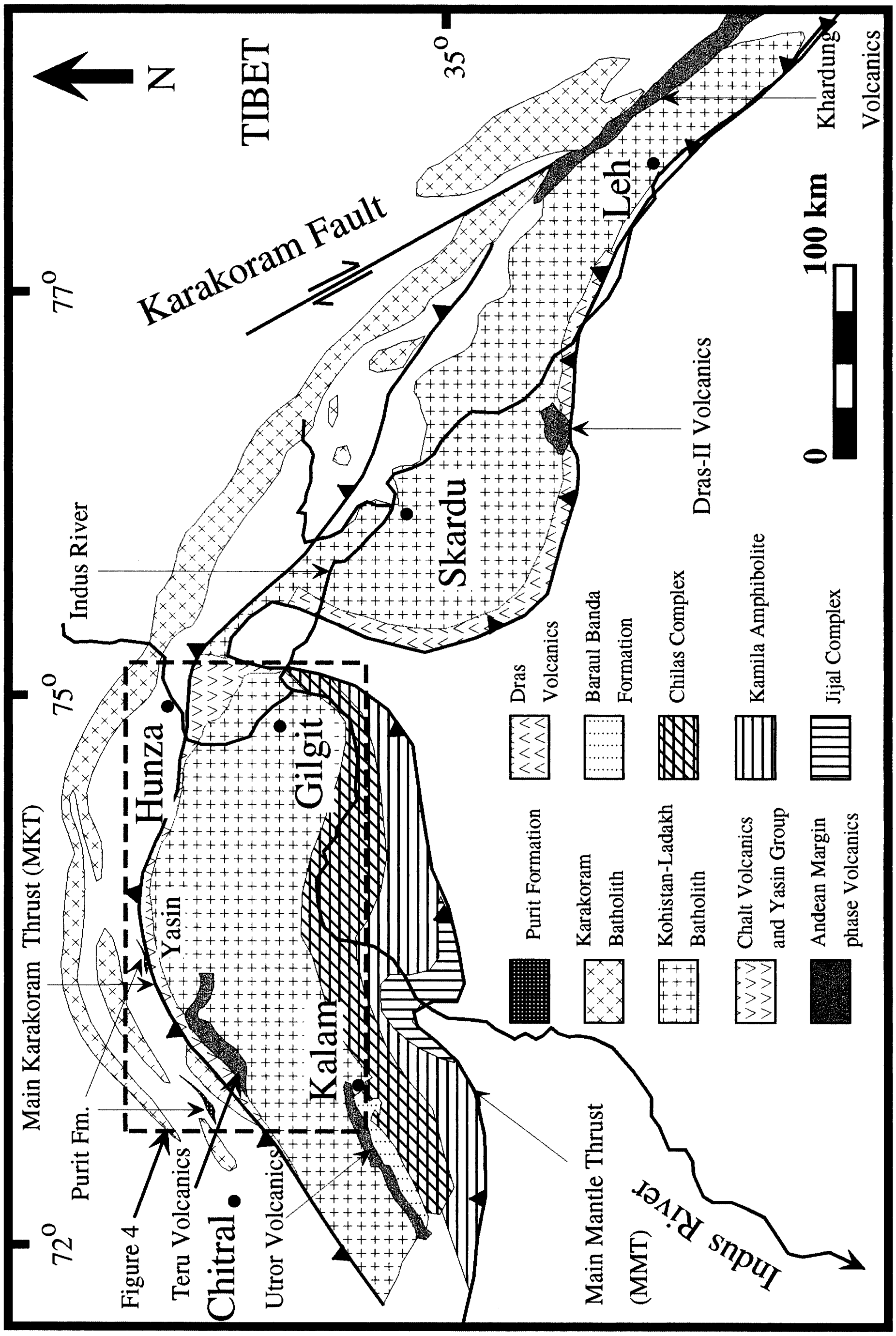

Fig. 3. General geological map of the Kohistan–Ladakh terrane (modified from Searle and Khan, 1996; Sharma, 1991).

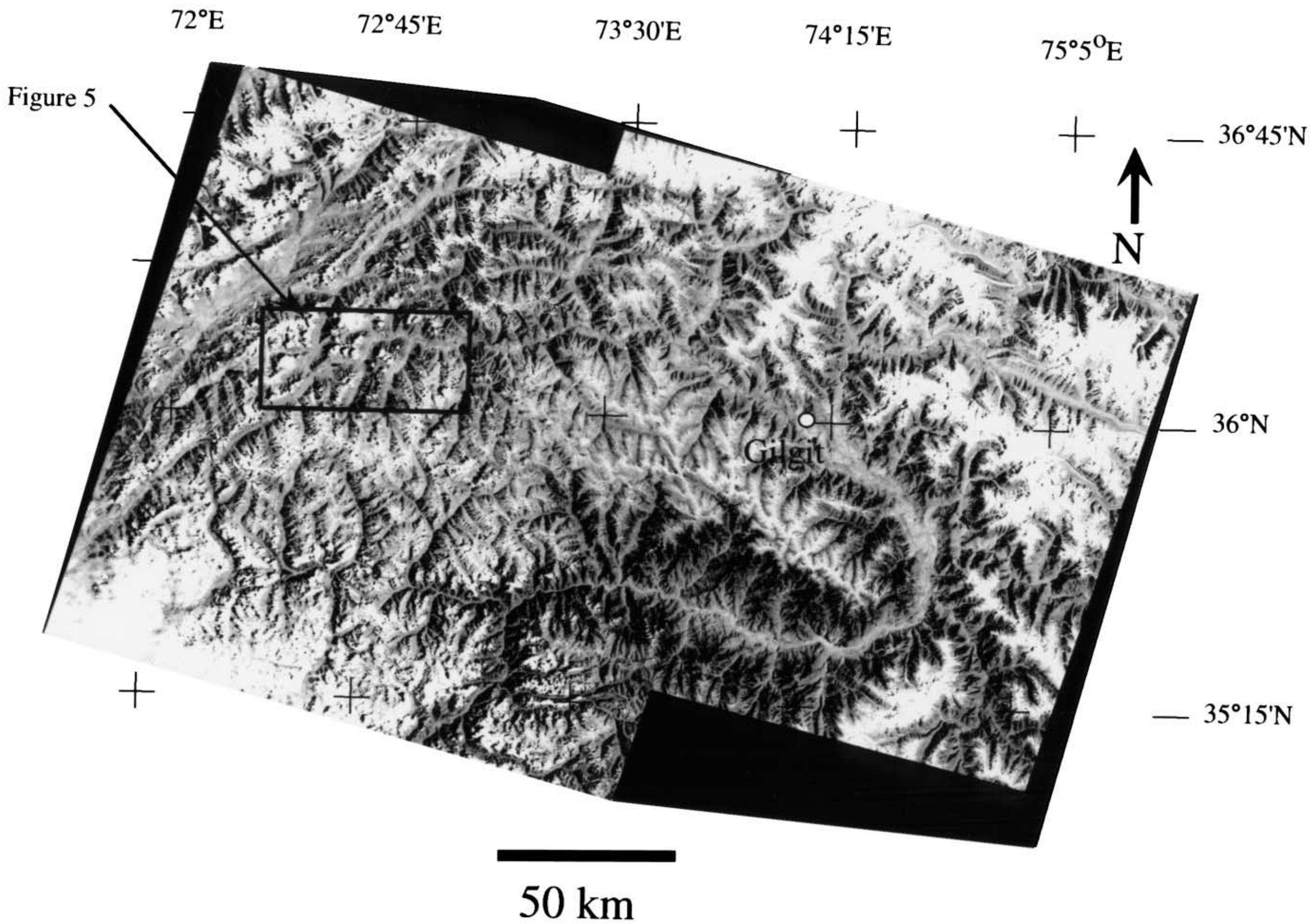

Fig. 4. Location of the study area on georeferenced landsat multi spectral scene.

found that the alluvial plain, on which Shamran village lies, is built upon the Chalt volcanic group (Fig. 5), while boulders of unmetamorphosed volcanics were transported from outcrops farther west or south. Shamran village is therefore, not a suitable type locality for these volcanics and the name 'Shamran volcanics' should be abandoned.

During the present study, outcrops of relatively fresh and unmetamorphosed volcanic rocks were found for the first time. The best outcrop of these volcanics can be seen near the village of Teru, so the name Teru volcanic formation is a more appropriate term for these rocks. A map produced as a result of these studies is shown in Fig. 5.

4. Field relations

The Teru volcanic formation unconformably overlies the Shunji Pluton [Fig. 5, Sp and Fig. 6(a)] that is part of the Cretaceous–Paleogene Kohistan batholith. In the northeast, near Shamran village, these volcanic rocks are intruded by the Pingal Pluton [Fig. 5, Pp and Fig. 6(b)]. To the north and northwest, the Teru volcanic formation is overthrust by the Cretaceous Chalt volcanic group across a previously unknown, south-verging, north-dipping thrust fault named here the Ghizer thrust, after the Ghizer River. In the hanging wall of the Ghizer thrust there is a major south-verging syncline named here the Harchin syncline. The Harchin syncline deforms Cretaceous supracrustal sequences of the Chalt volcanic group and the fossiliferous Yasin group. The presence of the Yasin group in the core of this syncline is one of the reasons that all the volcanics in this area, including the Teru volcanic formation, were previously thought to be Cretaceous in age (Pudsey et al., 1985b).

5. Teru volcanic formation

A stratigraphic column for the Teru volcanic formation is shown in Fig. 7. The type section near Teru village comprises an approximately 3-km thick sequence of subaerially erupted, mafic to felsic lavas with associated volcaniclastics and pyroclastics. The sequence consists of two cycles, cycle 1 and cycle 2, which overlie the Shunji Pluton across a nonconformity. Cycle 1 is about 1200-m thick and starts with a 300-m thick sequence of andesites with intercalated pyroclastics. The andesites are overlain by

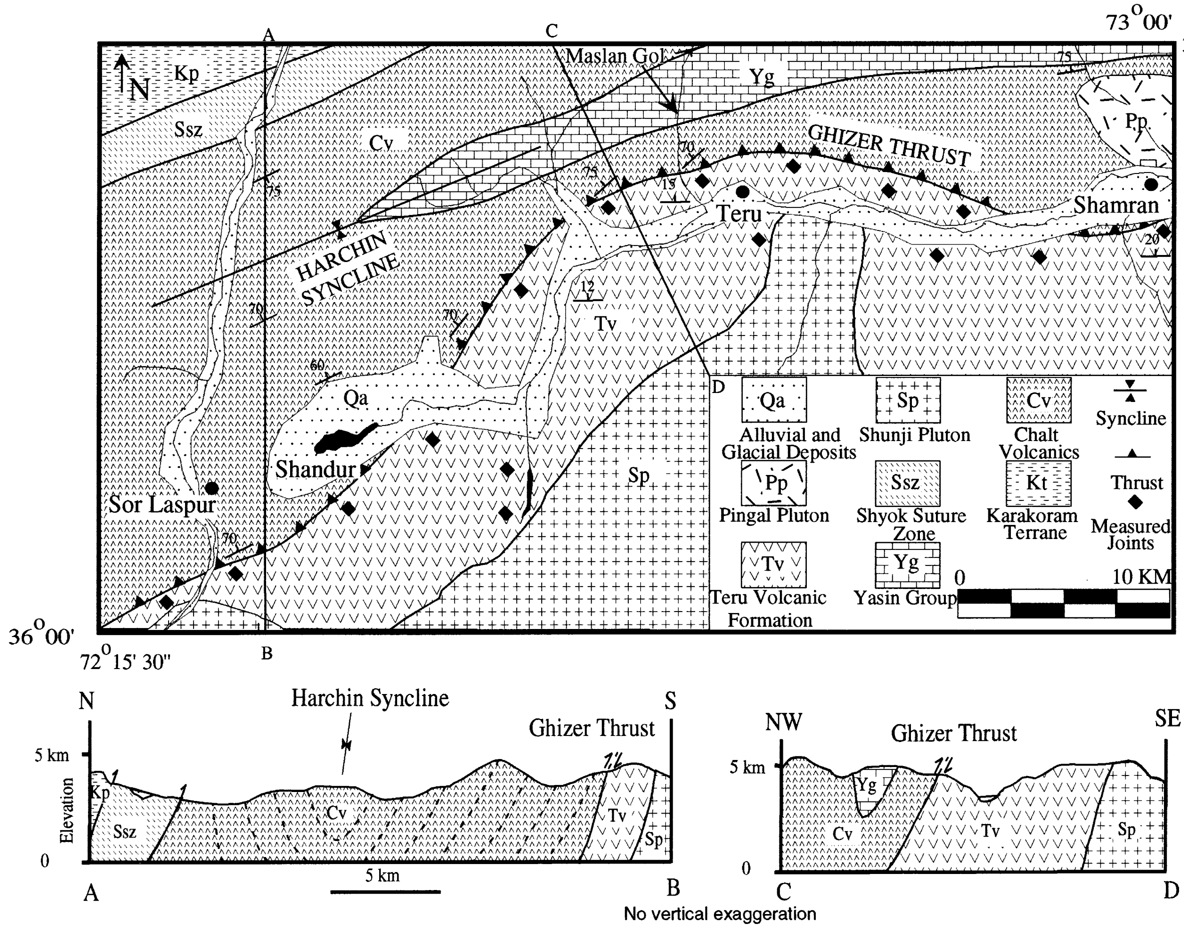

Fig. 5. Geological map and cross-sections of the Teru area, northern Kohistan terrane, Pakistani, Himalayas.

a 100-m thick sequence of pyroclastics, followed by 600 m of basalt and basaltic andesite. The uppermost unit of cycle 1 consists of 160 m of rhyolite. Cycle 2 starts with a thick ($\approx$ 1000 m) sequence of pyroclastics, which is succeeded by about 480 m of andesites with intercalated pyroclastics. The Ghizer thrust truncates the top of the section, with a 100-m thick mylonite zone affecting the Teru volcanic formation in the footwall. The Teru volcanic formation show patches reflecting the early stages of low temperature alteration caused by hydration and oxidation. With the exception of mylonitization near the thrust, the volcanics are relatively undeformed.

Rocks of the Teru volcanic formation include basalt, trachybasalt, basaltic andesite, basaltic trachyandesite, andesite, trachyandesite, dacite and rhyolite. Basaltic rocks contain hornblende, clinopyroxene and plagioclase phenocrysts in a groundmass of chlorite, epidote and opaque minerals. Plagioclase is altered to sericite and in some cases only pseudomorphs of plagioclase are visible. Clinopyroxene is altered to chlorite. In lava flows, the dominant rocks are basaltic andesites and andesite (Fig. 8). These rocks are hornblende–plagioclase porphyries typical of convergent margin suites. Phenocrysts vary from 2–6 mm in size, while the groundmass is fine to cryptocrystalline. These rocks show little alteration. Plagioclase is variably altered to sericite. In a few cases, plagioclase phenocrysts are partially resorbed by the groundmass. Hornblende is mostly greenish in color and shows alteration to chlorite at grain margins. Rare phenocrysts of oxyhornblende are pleochroic from gold to russet, fringed with magnetite. Occasional phenocrysts of clinopyroxene are observed, which in most cases are augite displaying sector zoning. The groundmass mostly consists of fine-grained plagioclase, hornblende, clinopyroxene, and opaques and displaying intergranular, ophitic and subophitic textures. Some of these rocks contain autoliths of different volcanic rocks. The rhyolites and dacites are porphyritic with feldspar phenocrysts and occasionally manifest amygdaloidal texture and flow banding.

6. Structure

6.1. Ghizer thrust

The Ghizer thrust is a north-dipping thrust fault separating the Paleogene Teru volcanic formation in the south from

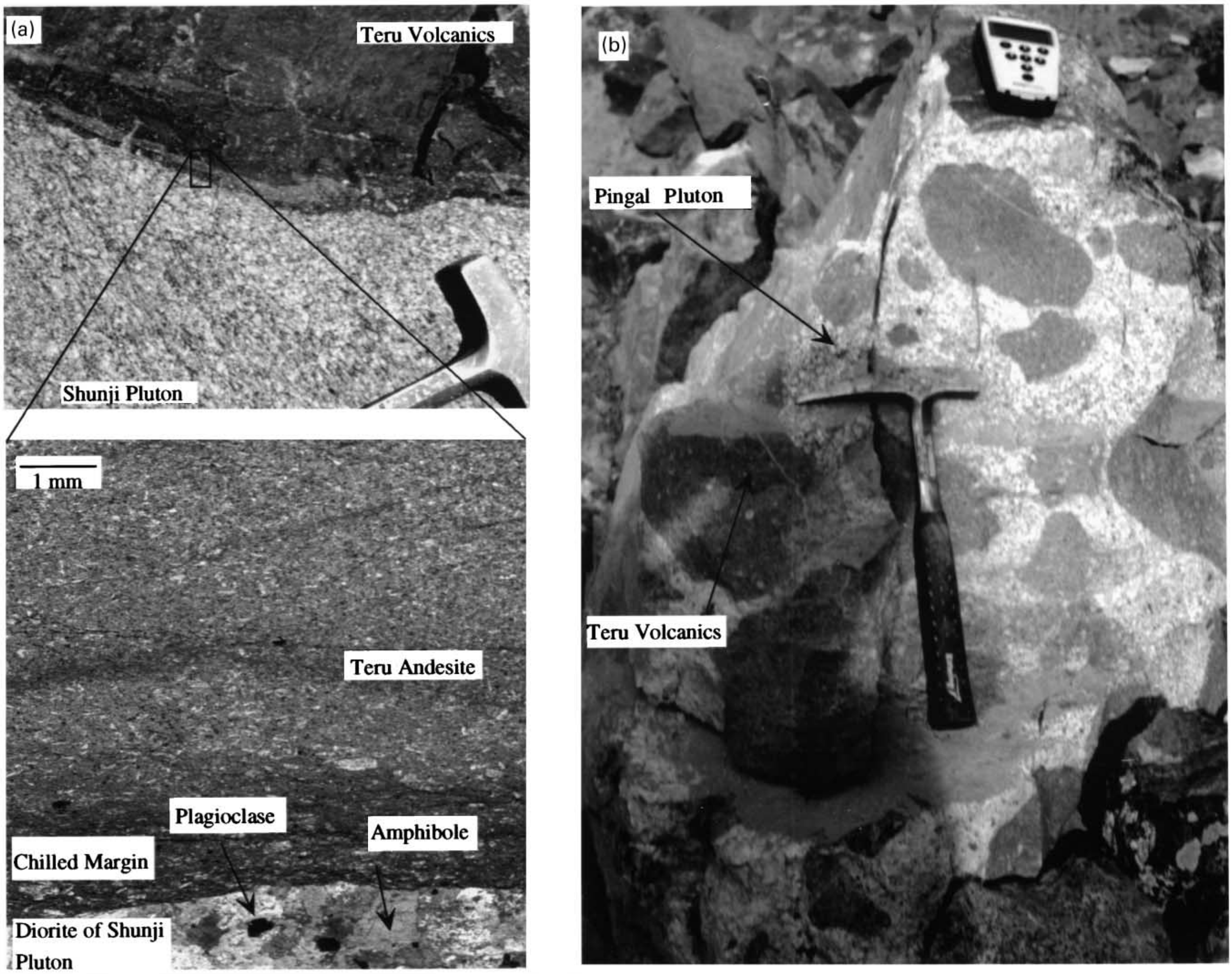

Fig. 6. (a) Photograph and photomicrograph showing the non-conformable contact of the Teru volcanic formation and Shunji Pluton. (b) Biotite granite of the Pingal Pluton with xenoliths of from the Teru volcanic formation.

the Cretaceous Chalt volcanic group. North of the village of Teru, this fault strikes E–W and dips 65° north [Figs. 5 and 9(a)]. The Chalt volcanic group in this area is metamorphosed to greenschist facies and consist of chlorite, epidote, plagioclase, and amphibole. The dominant foliation within the Chalt volcanic group near the thrust strikes E–W and dips 70° north. The grade of metamorphism decreases northward away from the thrust. The Ghizer thrust includes deformed Teru andesites and a 100-m thick zone of orthomylonite. The term orthomylonite is used for a coherent rock with foliated, moderately recovered matrix in which syntectonic recrystallization has reduced the grain size of the country rock to less than 0.5-mm diameter and left 10–50% of that material as surviving megacryst (Wise et al., 1984). Down-dip slickensides are also observed near the fault zone [Fig. 9(b)].

The orthomylonite consists of 30% porphyroclasts (25% plagioclase, 5% biotite and chlorite) and 70% finely granular streaked-out matrix [Fig. 9(c)]. The plagioclase porphyroclasts range in size from 0.2 mm to 1.5 mm across. Fine-grained secondary mica and chlorite wrap around porphyroclasts of plagioclase, thus the fabric postdates the orthomylonite [Fig. 9(c)]. The mica exists either as thin ($\sim$10 μm) seams within plagioclase domains or in wider mica-rich regions up to 1 mm thick, which are contiguous and anastamatose around the mica-poor regions.

Fig. 9(d) is a scanning electron microphotograph showing a plagioclase porphyroclast, which has developed cracks along weak planes. This is a common feature of mylonites, in which continued shearing rotates the rigid grains and the fragments of each grain slide past one another along the cracks, allowing the grain to extend in the direction of flow (Marshak and Mitra, 1988).

The Ghizer thrust was traced to the east as far as Shamran village, where the Pingal Pluton intrudes the Teru volcanic formation. The Ghizer thrust at the contact of the Teru volcanic formation and Pingal Pluton shows strike-slip movement. This relationship was observed only at a

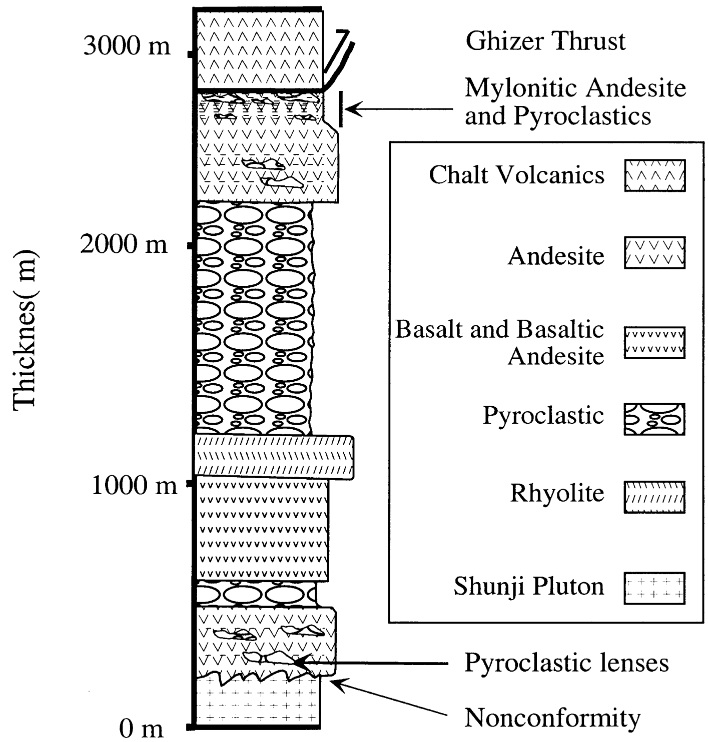

Fig. 7. Stratigraphic column of the Teru volcanic formation near Teru village.

distance, because the outcrop was across the Ghizer River at high altitude. In the west the thrust was traced up to the Sor Laspur section (Fig. 5).

6.2. Contact with Shunji Pluton

The southern contact of the Teru volcanic formation at the type section represents a nonconformity with the Shunji Pluton. The term Shunji Pluton is used for plutonic rocks of the Kohistan batholith consisting of at least two different varieties, diorite and granite. Fig. 6(a) depicts the outcrop and photomicrograph of this nonconformable contact. The chilled margin of the andesite and the fact that the contact truncates both amphibole and plagioclase grains of the diorite indicates that the andesite is younger than the diorite. In the Sor Laspur section, diorite lies close to the Ghizer thrust where it is foliated. The fabric of the diorite generally dips northwestward and strikes NE–SW. These diorites are inferred to be older than the Teru volcanic formation.

In the northeastern part of the study area near Shamran village, a biotite granite is exposed. This pluton is part of the Pingal Pluton (Treloar et al. 1989). A biotite age of 44 ± 2 Ma and hornblende age of 52 ± 2 Ma has been reported for this granite (Treloar et al., 1989). This granite contains xenoliths of the Teru volcanic formation [Fig. 6(b)], and there is an intrusive contact between the Teru volcanic formation and the granite. These features indicate that this granite is younger than the Teru volcanic formation.

6.3. Joints

The Teru volcanic formation reveals a well-developed, systematic joint system as shown in Fig. 10(a). Orientation of joint sets was measured at sixteen different sites within the Teru volcanic formation (Fig. 5). The data show two dominant orientations for the joints, J1 and J2 [Fig. 10(b)]. The joint sets J1 are oriented NNE and are vertical, while the J2 sets are oriented ESE and are also vertical. The frequency of these joint sets increases from south to north towards the Ghizer thrust. The length of the joint sets varies from less than a few meters to tens of meters. It appears that joint sets J1 and J2 are stress joints associated with the Ghizer thrust. Other minor joint sets seen in the rose diagram [Fig. 10(b)] may have developed during cooling of the lavas.

6.4. Harchin syncline and Shyok suture

In the Mashalan Gol stream section, an inaccessible outcrop inferred to be part of the Yasin Group is exposed (Fig. 5). Long distance views of this outcrop and associated boulders show that the outcrop consists of bedded limestone, volcaniclastic sandstone, and mostly red shale. Based on the presence of fossils, Pudsey et al. (1985b) assigned an Aptian/Albian age to the sediments of the Yasin group. These sediments define the core of a syncline named here the Harchin syncline after a nearby village. The Harchin syncline has a fold axis oriented SW–NE and is

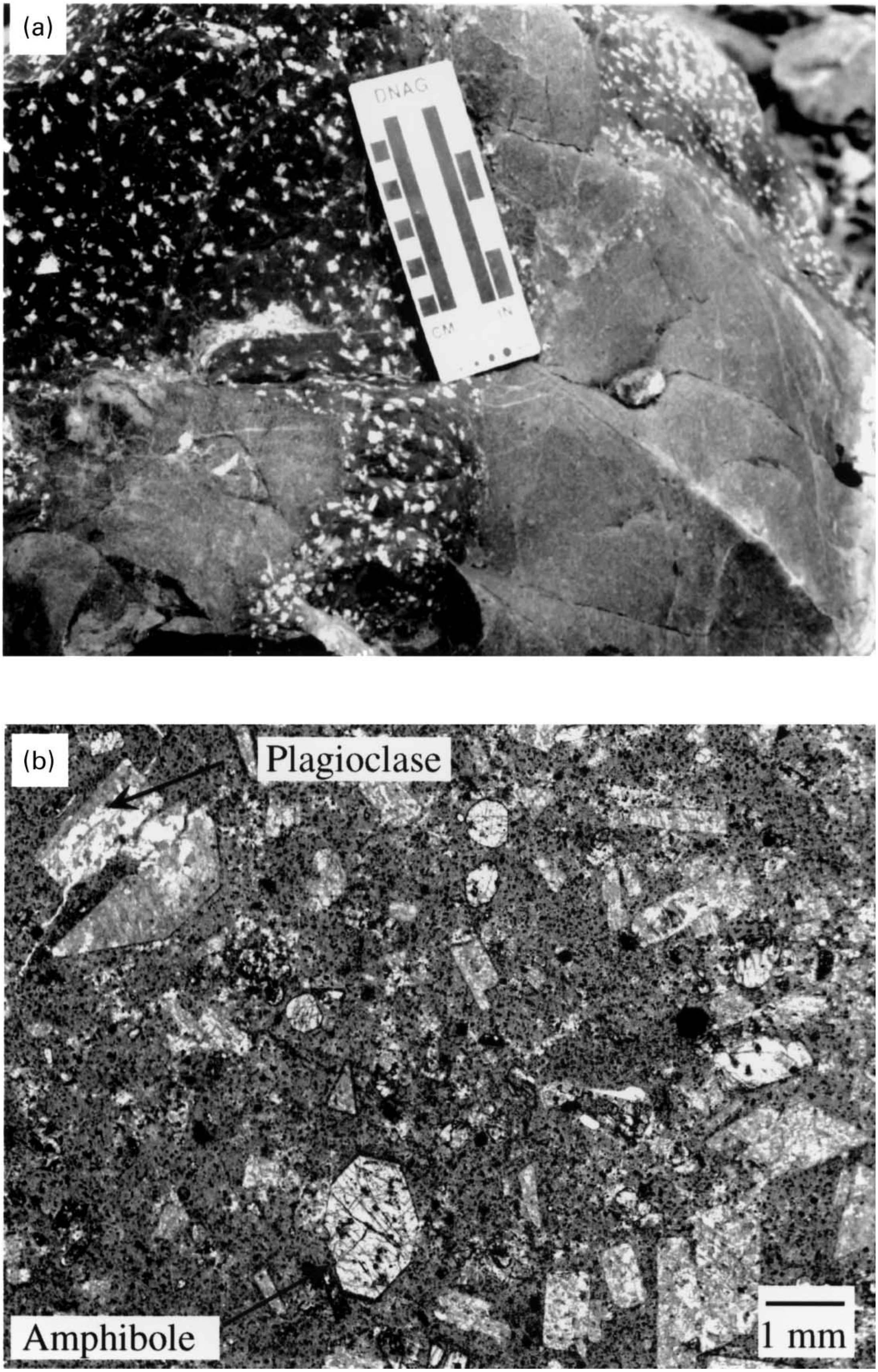

Fig. 8. Teru volcanic formation: (a) a typical outcrop of typical of the Teru volcanic formation; (b) photomicrograph of andesite showing plagioclase and hornblende phenocrysts in a fine-grained groundmass. Note absence of deformation and metamorphism.

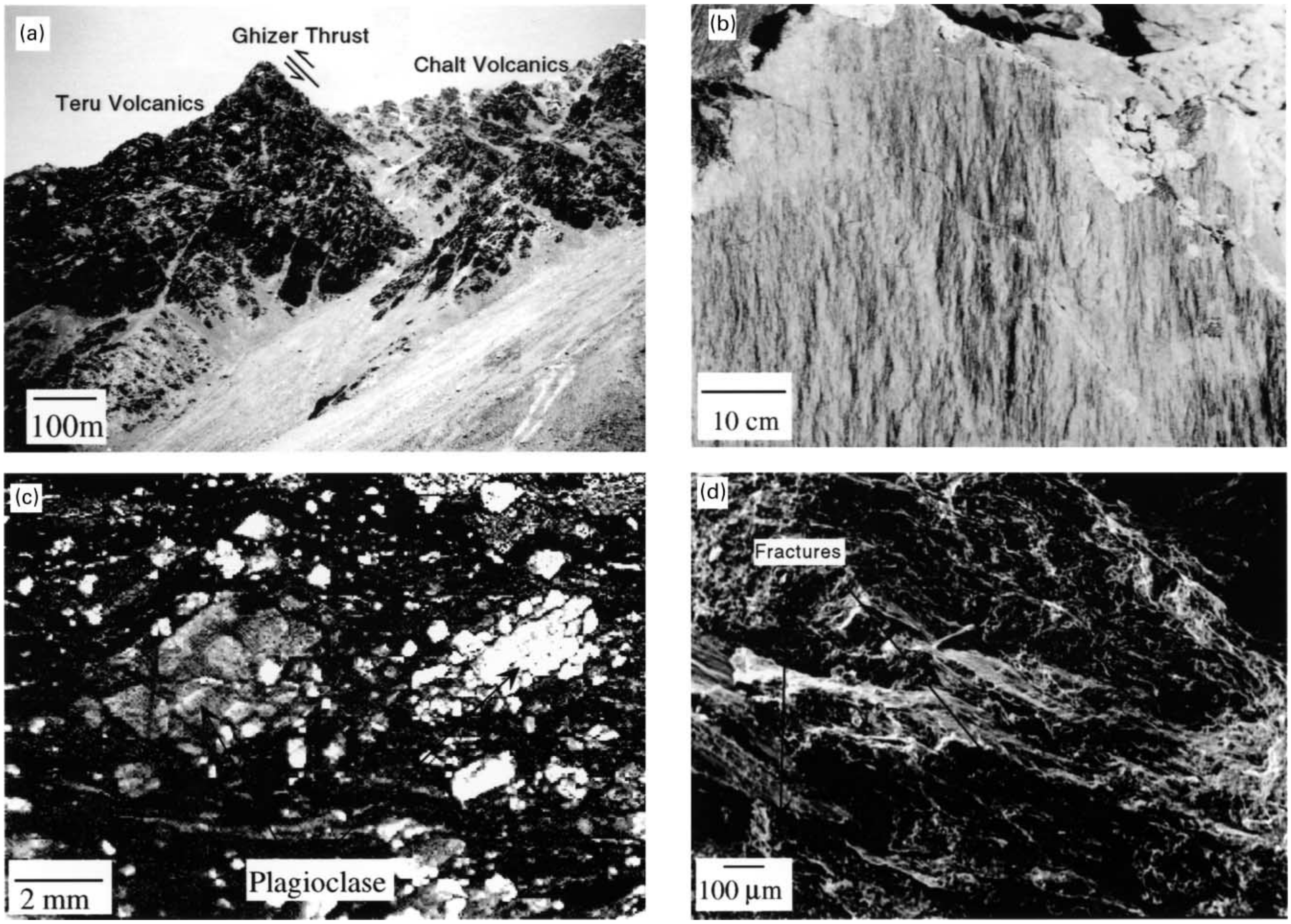

Fig. 9. (a) Ghizer thrust, thrusting the Chalt volcanic group over Teru volcanics. (b) Slickenlines in the Ghizer thrust zone. (c) Photomicrograph showing plagioclase porphyroclasts in a fine grained crushed groundmass. (d) Scanning electron microphotograph showing fractures developed in plagioclase grain in mylonite.

slightly overturned to the south, giving a sense of vergence in that direction. The limbs of this syncline are composed of the Cretaceous Chalt volcanic group. The northern limb of the syncline in the northwestern part of the study area shows tight, overturned folds that merge with the Shyok suture zone. The Shyok suture in this area is around 2.5 km wide and consists of blocks of volcanics, limestone, shale, conglomerate, quartzite and serpentine (Pudsey, 1986). Coward et al. (1987) recognized upright, southward-verging structures associated with the Shyok suture. Thus, the Harchin syncline appears to be associated with the collision of the Kohistan and Karakoram plates.

7. Discussion

7.1. Geological implications

The Teru volcanic formation of northern Kohistan appears to represent the Andean margin phase of the Himalayan convergent plate boundary. $^{39}Ar/^{40}Ar$ dating of a hornblende sample thought to be part of these volcanic rocks yielded an age of 58 ± 2 Ma (Paleocene; Treloar et al., 1989). Based on this age and on preliminary field studies, Sullivan et al. (1993) proposed the presence of Andean margin phase volcanic rocks in this part of Kohistan. The present study discovered a relatively complex sequence of rocks. Similar volcanic sequences are reported from other parts of the Himalayas (Fig. 2), which include the 55 ± 2 Ma Utror volcanics (southern Kohistan terrane; Treloar et al., 1989), Cretaceous to Neogene Khardung volcanics (eastern Ladakh terrane; Trommsdorff et al., 1982; Sharma 1991), Early Tertiary Dras-II volcanics of western Ladakh (Reuber, 1989) and the 60–50 Ma Linzizong volcanics (Lhasa terrane; Coulon et al., 1986; Pearce and Houjun, 1988).

The Teru volcanic formation has a nonconformable contact with the Shunji Pluton and has been intruded by the Pingal Pluton. Due to the Ghizer thrust, the Teru volcanic formation is in direct contact with the Chalt volcanic group to the north. The Ghizer thrust is intruded by biotite granite of the Eocene Pingal Pluton (Treloar et al., 1989). This relationship constrains the tectonic movement on the Ghizer thrust to Eocene in age, somewhere between

58 and 52 Ma (Treloar et al., 1989). In light of the facts given, it appears that the Ghizer thrust resulted from the deformation of Kohistan due to its collision with the Indian margin.

Sullivan et al. (1993) mapped several thrust faults in the Kalam area (see Fig. 3), These thrust faults locally rework intrusive contacts between the Kohistan batholith and the Utror volcanics. A upper limit of 48 Ma has been assigned for the age of this deformation (Sullivan et al., 1993). Moreover, Coward et al. (1987) inferred over 2000 km of shortening north of the main mantle thrust MMT (Fig. 3) since the initial collision of the Indian plate with Kohistan. Much of this shortening was taken up by thrust and/or strike-slip tectonics in northern Kohistan, Hindu Kush and the Pamirs (Coward et al., 1987). Krol and Zeitler (1996) determined the cooling histories for the Kohistan batholith using multi-diffusion domain analyses of the $^{39}Ar/^{40}Ar$ system on K-feldspar. Their results show systematic variations along the length of the batholith, suggesting that Kohistan experienced differential unroofing. An episode of rapid cooling in the middle Eocene is recognized in western Kohistan. Krol and Zeitler (1996) concluded that Kohistan may not have acted as a completely rigid block following collision with India but may have been deformed by localized shears and faults.

7.2. Tertiary palaeogeography

Fig. 11 summarizes our tectonic model. Kohistan collided with the Karakoram plate in the Late Cretaceous, whereby Kohistan was transformed from an island arc into an Andean-type convergent margin (Treloar et al., 1989; Petterson and Windley, 1985). This was followed by an extensive period of subaerial volcanism and stage 2 Kohistan batholith plutonism. The Teru volcanic formation and Utror volcanics are the extrusive equivalent of this event. A fore-arc basin was also formed, which in turn was filled by 2700 m of sandstones, siltstones and rare limestone of the Baraul Banda formation (Sullivan et al., 1993). To the north in the Karakoram plate, the youngest sediments are those of the Purit formation, which mainly include red shales and conglomerates (Searle and Khan, 1996). Pudsey (1986) described part of the Purit formation in the Yasin area (Fig. 3), where it consists of massively bedded pebble and cobble conglomerate with moderately rounded clasts of fine-grained volcanic rocks (about 1/3 of all the clasts), recrystalized limestone, gray and green slates and volcanic–lithic sandstones. The matrix consists of coarse volcanic–lithic sandstone (Pudsey, 1986). Searle and Khan inferred a late Cretaceous–Eocene age for the Purit formation. A detailed study of the Purit formation is needed, but the presence of porphyritic volcanic clasts, the terrigenous origin of the rocks and the supposed age of this formation indicate that it may represent the back-arc deposits of the Teru–Utror continental arc.

Andean margin phase igneous activity was terminated by the collision of India with Kohistan in the Early Tertiary (Coward et al., 1986; Treloar et al., 1989; Beck et al., 1995). This collision was followed by uplift and erosion of Kohistan. This event removed most of the Andean margin phase volcanic rocks, which at that time was the uppermost unit of the Kohistan terrane. Today we only see a few remnants of the Andean margin phase volcanic rocks at the margins of the Kohistan batholith.

The following evidence supports this argument;

1. Middle Eocene uplift of western Kohistan as indicated by Krol and Zeitler (1996).
2. Cerveny et al. (1989) inferred from the blue–green hornblende of the Miocene Siwalik group that the Kohistan terrane was unroofed rather suddenly and became a source of blue–green hornblende that was deposited onto the Indo–Gangetic plain.
3. Zeitler (1985), using fission track and $^{40}Ar/^{39}Ar$ cooling ages of the Kohistan batholith, found that the central and northwestern regions of the Pakistani Himalayas, including the present study area, may have been uplifted

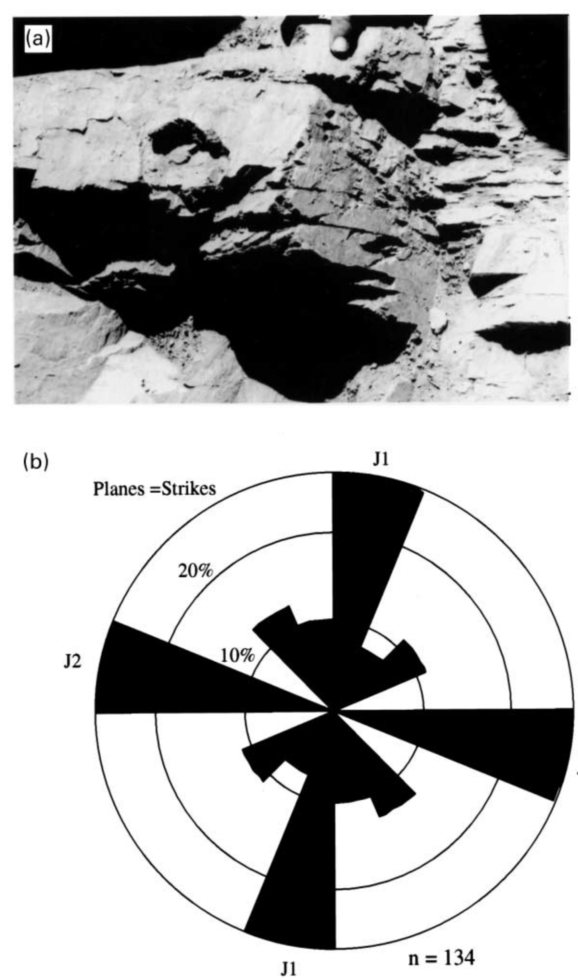

Fig. 10. (a) Photograph showing typical joint sets developed in the Teru volcanics. (b) Rose diagram showing joint orientation data for the Teru volcanic formation.

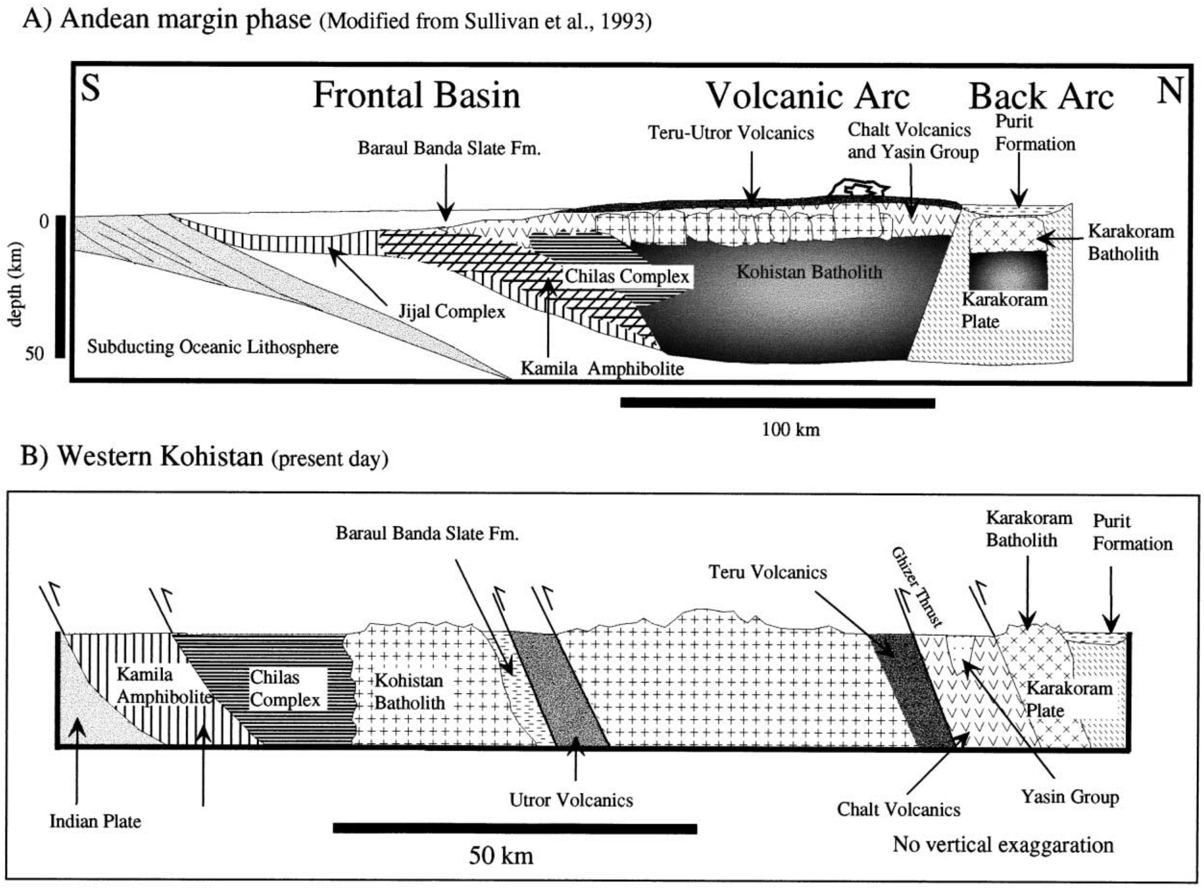

Fig. 11. Simplified schematic section through the Kohistan terrane showing the evolution of Andean margin phase volcanism. Cross-sections illustrating present day western Kohistan is also shown.

between 3 and 6 km over the last 10 Ma. The north-eastern regions (Nanga Parbat area) may have been uplifted at least 6 km, while locally over 10 km of uplift may have occurred.

8. Conclusions

1. A section of Andean margin style volcanic and volcaniclastic rocks called the Teru volcanic formation in the northern Kohistan terrane have been discovered.
2. The Ghizer thrust defines the contact between the Teru and Chalt volcanic group. This thrust is Eocene in age.
3. The Teru volcanic formation has a non-conformable contact with the Shunji Pluton of the Kohistan batholith and has been intruded by the 52 Ma Pingal Pluton.
4. The Teru volcanic formation is similar to the Andean margin phase volcanic remnants exposed in other parts of the Himalayas.
5. A laterally extensive Andean-type arc developed which extended over 1500–2000 km along the southern margin of Asia prior to collision with India.
6. After collision, Kohistan went through a phase of uplift and erosion, which removed most of the volcanic rocks. Representative Andean margin phase volcanics are only present along the margins of the Kohistan batholith.

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