Geochemistry and petrogenesis of the sheeted dykes in Waziristan Ophiolite, NW Pakistan and their tectonic implications

S.R. KHAN[a], M.Q. JAN[b],
M.A. KHAN[b], T. KHAN[a]
[a]Geoscience Laboratory, Geological Survey of Pakistan, Shahzad Town, Islamabad, Pakistan
[b]Department of Geology and National Centre of Excellence in Geology, University of Peshawar, Peshawar, Pakistan

This paper presents the petrologic and geochemical aspects of the sheeted dykes as well as isolated mafic dykes from the Waziristan Ophiolite, northwest Pakistan. The ophiolite occurs in the suture zone between the Indian plate to the east and Afghan block to the west. It is divisible into three main sheets or nappes which, from east to west are: Vezhda Sar nappe entirely comprising of pillow basalts; Boya nappe made up of ophiolitic melange with an intact sequence in the basal part; and Datta Khel nappe consisting of sheeted dykes along with small proportions of other components. The sheeted dykes are an important component of the Waziristan Ophiolite and their excellent exposure is found in the hanging wall of the Datta Khel Thrust, ENE of Datta Khel. The ophiolite is thrust over the Mesozoic shelf-slope sediments of the Indian plate to the east and unconformably overlain by sedimentary rocks of Early to Middle Eocene age to the west.
Major and trace element geochemistry indicate that the dykes (both sheeted and isolated) contain higher contents of Na_2O, FeO^t/MgO and LILLE/HFSE ratios, and lower TiO_2 (<0.1 wt%) and K_2O (Figs. 1 and 2). Non-depletion of Nb and high LILE/HFSE ratio negate an island-arc or mid-ocean ridge settings for these dykes, respectively. The enrichment of LILE rather suggests involvement of crustal components driven by fluids along a subduction zone. The various geochemical parameters used in specifying the tectonomagmatic setting of the Waziristan dykes reveal a transitional characteristic between mid-ocean ridge basalt and island-arc tholeiite. It is suggested that the Waziristan dykes may have originated in a back-arc basin tectonic set-up.
Based on the age of the radiolarian fauna (Tithonian–Valanginian) recovered from the pelagic sediments (cherts), the age of the Waziristan Ophiolite is interpreted as Late Jurassic or older. The presence of exotic blocks of the Campanian limestone in the ophiolite coupled with overthrusting of the ophiolite onto Maastrichtian rocks suggest post-Maastrichtian, most probably Paleocene, emplacement of the Waziristan Ophiolite.

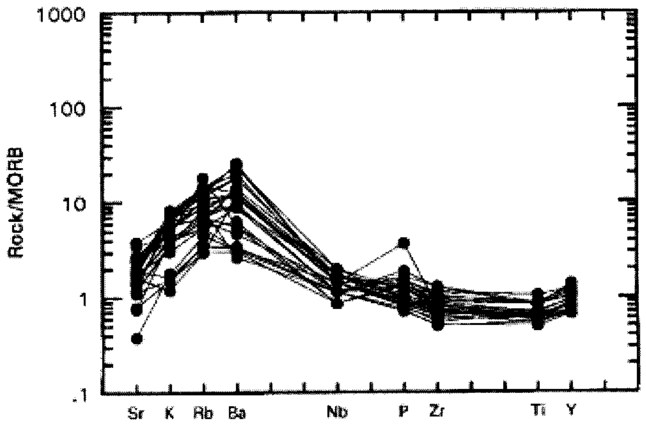

Fig. 1. N MORB-normalized spider diagram for the Waziristan dykes (after Pearce, 1983).

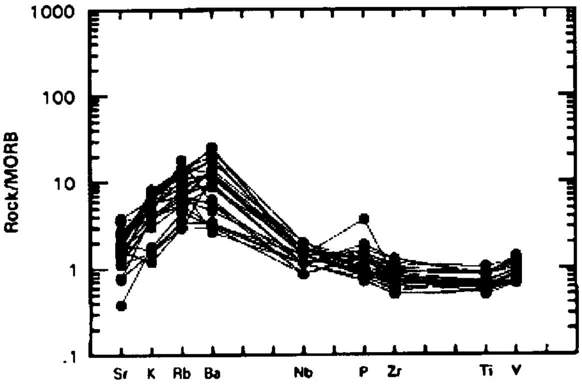

Fig. 2. Primordial mantle-normalized spider diagram for the Waziristan dykes (after Wood et al., 1979).

References

Pearce, J.A., 1983. Role of sub-continental lithosphere in magma genesis at active continental margins. In: Hawkisworth, C.J., Norry, M.J. (Eds.), Continental Basals and Mantle Xenolithes. Shiva, pp. 230–240.
Wood, D.A., Joron, J.L., Treuil, M., 1979. A re-appraisal of the use of trace elements to classify and discriminate between magma series erupted in different tectonic settings. Earth Planet Sci. Lett. 45, 326–336.

New geological map of the Nanga Parbat–Haramosh massif

W.S.F. KIDD[a], M.A. EDWARDS[a,b],
D.A. SCHNEIDER[c,d], M.A. KHAN[e]
[a]Earth and Atmospheric Sciences, University at Albany, Albany, NY 12222 USA
[b]Institut für Geologie, Technische Universität Bergakadamie Freiberg, Freiberg, D-09596 Germany
[c]Department of Earth and Environmental Sciences, Lehigh University, Bethlehem, PA 18015 USA
[d]Department of Geology, Syracuse University, Syracuse, NY 13244 USA
[e]National Centre for Excellence in Geology, University of Peshawar, Peshawar, Pakistan

We present a newly compiled detailed geological map (1:100 000 scale) of the Nanga Parbat–Haramosh massif based on our field work during the 1995–8 continental dynamics collaborative project, building from previous work by others (references on the map, and below), and supplemented by interpretation from an excellent cloud-free Landsat thematic mapper image taken in October 1995. Major geological features relevant to the young rapid uplift and denudation of the NPHM include the Raikhot fault and its precursor shear zone, first identified by Madin (1986), which is the main structure developed by the W- to WNW- directed thrusting and exhumation of the NPHM over the past 5–10 Ma. Our work has extended the identification and location of this fault and shear zone from Raikhot Bridge to the southwest through the Diamir valley, and shown the coincidence of this zone with the young Jalhari granite from the Diamir valley southwards (Edwards et al., 2000). Our work also documents the extent and shear sense of ductile shear associated with the Diamir–Raikhot shear zone (DRSZ) and distinguishes older ductile shear and mylonite zones, originally developed by S- to SW-directed thrusting, and some subsequent N-directed low angle normal sense motion, during the earlier 'Himalayan' events. The map also documents that the eastern NPHM-Kohistan contact is in most places only folded by the NPHM event, with local young faults in this zone being much less abundant and not a continuous zone, unlike the Raikhot fault on the western margin. Our mapping shows that there is significant E- to NE- directed, mainly ductile displacement on the eastern margin of the main antiform of the Nanga Parbat part of the NPHM, expressed by a wide S/C ductile shear zone in the Chhichi and central Rupal valleys, which continues northwards as a narrower tightly pinched synclinal/ shear zone structure at least to Shengus village in the Indus gorge (Schneider et al., 1999b). This Rupal–Chhichi shear zone (RCSZ) and its northward continuation is well within the NPHM, and does not directly affect the eastern NPHM-Kohistan contact. Some younger brittle faulting is associated with this zone in the Rupal valley, but it is not nearly as prominent as that associated with and defining the Raikhot fault on the western margin of the massif. The RCSZ forms the secondary part of a crustal-scale pop-up structure conjugate to the DRSZ and Raikhot fault. Besides the quaternary fault along surface trace of the Raikhot fault, some other active fault traces are developed in the Kohistan block to the west, up to as much as 15 km from the Raikhot fault. The map includes the newly discovered Himalayan leucogranite of Miocene age in southernmost Chhichi Nullah (Schneider et al., 1999a).

References

Butler, R.W.H., George, M., Harris, N.B.W., Jones, C., Prior, D.J., Treloar, P.J., Wheeler, J., 1992. J. Geol. Soc. 149, 557–567.

Edwards, M.A., Kidd, W.S.F., Khan, M.A., Schneider, D.A., 2000. Tectonics of the southwest margin of the Nanga Parbat massif. Tectonics of the Nanga Parbat Syntaxis and the western Himalaya, Khan, M.A., Treloar, P.J., Searle, M.P., Jan, M.Q. (Eds.). Geol. Soc. Lond., Spec. Pub. 170, 77–100.

Edwards, M.A., 1998. Unpublished PhD dissertation, University at Albany, p. 308.

Laurs, B.M., Dilles, J.H., Wairrach, Y., Kausar, A.B., Snee, L.W., 1996. Unpublished manuscript.

Lemennicier, Y., Le Fort, P., Lombardo, B., Pecher, A., Rolfo, F., 1996. Tectonophysics 260, 119–143.

Madin, I.P., 1986. Unpublished MSc Thesis. Oregon State University.

Madin, I.P., Lawrence, R.D., Ur-Rehman, S., 1989. Geol. Soc. Am. Spec. Pap. 232, 169–182.

Map compiled from: field data of M.A. Edwards (1995-7), W.S.F. Kidd (1996–7), and M.A. Khan (1997).

Pecher, A., LeFort, P., 1999. Geol. Soc. Amer. Spec. Pap. 328, 145–158.

Schneider, D.A., Edwards, M.A., Kidd, W.S.F., Zeitler, P.K., Coath, C.D., 1999a. Early Miocene anatexis identified in the western syntaxis, Pakistan Himalaya. Earth Planet. Sci. Lett. 167, 121–129.

Schneider, D.A., Edwards, M.A., Kidd, W.S.F., Khan, M.A., Seeber, L., Zeitler, P.K., 1999b. Tectonics of Nanga Parbat, western Himalaya: synkinematic plutonism within doubly-vergent shear zones of a crustal-scale pop-up structure. Geology 27, 999–1002.

Paleosol of middle Holocene age and its paleoclimatic significance in Thakkhola basin, central Nepal

SAIJO KIYOSHI
Miyagi University of Education, Sendai 980-0845, Japan

Summer monsoons from the Indian Ocean provide much precipitation on the southern slope of the Himalayas. In contrast, the northern side is hardly affected by the monsoonal rainfall and is consequently dominated by semi-arid to arid climate. The Thakkhola basin in the upper Kali Gandaki River in central Nepal is a typical region free from the monsoonal rainfall. For example, Jomsom (ca. 2700 m a.s.l.), located in the southern part of the basin, had an annual mean temperature and precipitation of 11.6° and 298 mm, respectively, in 1990. As a result of such climate, a desert-like landscape characterized by sparse vegetation and poor soil development is dominant in the basin. Paleosols, however, are frequently recognized in surficial deposits, indicating some past environmental change in this region. The paleosols, which usually have a constant thickness less than 30 cm, are generally found in surficial deposits composed mainly of eolian and/or colluvium origin. They contain not only humus but also considerable inorganic matter. The results of radiocarbon dating suggest that most of them were formed around 5 ka. Charcoal fragments, pollen, as well as plant opals are more or less detected from the paleosols in the southern part of the basin. On the other hand, the paleosols distributed in the northern part of the basin yield no plant fossils. The carbon stable isotopes of the paleosols indicate that C_4 plants were dominant in the latter area while C_3 plants were rather rich in the southern basin during the period of the paleosols formation. The present climatic conditions in that the temperature is high enough for existence of forest suggest that types of vegetation and pedogenic processes in the Thakkhola basin are mainly controlled by amount of precipitation. The paleosols indicating the comparatively dense vegetation and rather active pedogenic processes around 5 ka mean that the climate was relatively humid at that time. The fact that this period of the paleosols formation almost corresponds with Hypsithermal interval shows that the relatively humid climate resulted from the increase of precipitation due to reinforced summer monsoon under the global climatic optimum. The characteristics of the plant fossils content and carbon isotopes suggest that the paleoenvironments of 5 ka were different in some degree between the northern and southern parts of the basin. It is estimated that trees could more or less exist in the southern basin while grasslands were dominant in the northern basin. Drier climate after the Hypsithermal interval reduced the precipitation of the summer monsoon, and the soils formed around 5 ka were buried in surficial deposits due to decline of vegetation and pedogenic processes.

The history of Himalayan erosion: what did we learn from the study of the modern system?

C. FRANCE-LANORD[a], A. GALY[b]
[a]CRPG-CNRS BP 20, Vanduvre-lès-Nancy, France
[b]Department of Earth Science, University of Cambridge, UK

The history of Himalayan erosion since Miocene is documented in the sedimentary record of both the Bengal Fan and the Siwaliks. A major change occurred 8 Ma ago when (1) weathering increased as documented by clay mineralogy, (2) savanna type of vegetation (C4) became dominant, and (3) Sr flux of the Himalayan rivers decreased possibly as a response to decreasing erosion flux. Recent studies of the modern Himalayan erosion from the High range to the modern Bengal fan allow to re-examine the causes of these variations.

Sources of sediments: Isotopic tracers (Sr, Nd) of sedimentary input in the Bengal Fan and in the Siwaliks show a dominance of HHC materials (e.g. France-Lanord et al., 1993). The isotopic composition of modern sediments from the Ganga and Brahmaputra are close to those of the Neogene sedimentary record (Galy and France-Lanord, 2001), implying a relative stability of detrital sources. The study of the repartition of erosion in the Central and Western Nepal shows that Thetian Sedimentary Series and High Himalaya Crystalline have rather similar isotopic signatures and that only the detrital carbonate flux allows to trace the proportion of these two formations. Such information is however not accessible from the sedimentary record. Erosion of the Lesser Himalaya (LH) is well revealed by Nd and Os isotopic compositions. Both Siwaliks and Bengal Fan sediments have isotopic compositions implying that LH were already exposed to erosion 20 Ma ago. The proportion of LH may have slightly increased with time to reach 20–30% in the Pliocene. In the detail, Ganga and Brahmaputra have different signatures related to the presence of

SPECIAL ABSTRACTS ISSUE

16th Himalaya-Karakorum-Tibet Workshop

3 – 5 April, 2001
Schloss Seggau

AUSTRIA

Guest Editors:

B. Grasemann (University of Vienna)
bernhard.grasemann@univie.ac.at
K. Stüwe (University of Graz)
kurt.stuewe@kfunigraz.ac.at

Volume 19 Number 3A April 2001

ISSN 1367-9120

Journal of Asian Earth Sciences

(Formerly the *Journal of Southeast Asian Earth Sciences*)

SPECIAL ABSTRACTS ISSUE

16th HIMALAYA-KARAKORUM-TIBET WORKSHOP, AUSTRIA

3–5 APRIL 2001

GUEST EDITORS

B GRASEMANN

K STÜWE

EDITOR-IN-CHIEF

PROFESSOR K BURKE

University of Houston, Houston, U.S.A.

DEPUTY EDITOR-IN-CHIEF

DR AJ BARBER

University of London, Egham, Surrey, U.K.

See the JOURNAL OF ASIAN EARTH SCIENCES on the World Wide Web http://www.elsevier.nl/locate/jseases

Pergamon