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Lead Isotopic Signature of the Hydrothermal Copper Mineralization in Drosh-Shishi Area, Chitral, Kohistan Arc Terrane, Northern Pakistan

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ABSTRACT: *Copper mineralization in Drosh-Shishi area is a part of the upper crust of Kohistan arc terrane in Chitral, northern Pakistan. It is generally confined to the Gawuch formation in the area. This formation comprises of variably metamorphosed volcanics and sediments intruded by plutons of diorite and granodiorite. Copper mineralization is related to the hydrothermal activity and is mainly associated with altered diorites and quartz veins.*

The lead isotopic ratios of three samples of galena from quartz veins in Drosh-Shishi area were determined. $^{206}Pb/^{204}Pb$ *from 18.728 to 18.793,* $^{207}Pb/^{204}Pb$ *from 15.658 to 15.728 and* $^{208}Pb/^{204}Pb$ *from 39.040 to 39.285. These lead-isotopic ratios yield wide range of model ages of 42 to 140 Ma. This mineralization is very young in terms of age and have* μ *values of 9.86 to 10.01. The studied galenas have comparable Pb-isotope ratios to that of Rossie-Type veins of USA and Canada and are more radiogenic to the conformable massive sulfides and less radiogenic to Mississippi Valley-Type sulfide deposits. The Lead isotopic data further suggest that the lead in galena may have been derived from the arc volcanics or pelagic sediments of ocean crust of Neo-Tethys or continental crust of Indian plate and may have relation with orogeny.*

INTRODUCTION

The geology of the NW margin of the Kohistan arc terrane in Chitral, including Drosh-Shishi area contains 1) Shyok suture melange, 2) volcano-sedimentary cover sequence and 3) Kohistan batholith. The Shyok suture melange in this area comprises lenticular blocks of serpentinized ultramafics, metavolcanics and metasediments. The volcano-sedimentary succession in this area is, however, much more complex than that of the Yasin-Hunza segment (for detail see Tahirkheli et al., 1979; Petterson & Windley, 1985; Pudsey et al., 1985; Pudsey, 1986; Khan et al., 1994). Pudsey et al. (1985) recognized three formations, which from south to north include 1) Gawuch Formation, 2) Purit Formation and 3) Drosh Formation Gawuch Formation comprises metabasalts and limestones and is probably marine in origin. Purit Formation comprising red conglomerates, sandstones and shale, and is fluvial in origin (Pudsey et al., 1985). Occurrence of a succession of andesite/dacite volcanics of the Drosh Formation to the north and probably over the Purit Formation points to the possibility of a phase of Eocene volcanic event similar to that of Dir-Utror (Shah et al., 1994; Shah & Hamidullah, 1994; Sullivan et al., 1993). Toward south, the Gawuch Formation, the host of the copper mineralization, is in contact with the Lowari pluton belonging to the Kohistan batholith. The contact probably intrusive in origin, is now strongly sheared and is occupied by phyllites derived from metavolcanics of the Gawuch Formation through mylonitization. Much of the lower half of the Gawuch Formation is occupied by metavolcanics which are locally strongly sheared and transformed into phyllites. The upper half of the Gawuch Formation comprises commonly intercalated metavolcanics and limestone/marble. This part of the Gawuch Formation is additionally commonly intruded by sills of diorite and granodiorite composition which are themselves pervasively intruded by quartz veins. The contact between the Gawuch Formation and the overlying Purit Formation is occupied by a 10 m thick band of marble.

Copper mineralization in this Formation is related to hydrothermal activity and is mainly associated with altered diorites and quartz veins. The mineralized rocks of the study area are divided into three units on the basis of both field and petrographic studies such as 1) sulphide-bearing quartz veins, 2) sulphide-bearing altered diorites and 3) sulphidebearing shear zone. Based on field observation, four types of copper mineralization are noticed in the area; 1) copper mineralization along quartz veins, 2) copper mineralization along foliation planes, 3) disseminated copper mineralization and 4) supergene enrichment of copper.

RESULTS AND DISCUSSION

Three samples of the galenas from the quartz veins of Gawuch Formation were analyzed for Pb-isotope at the University of Texas at Dellas, USA by using mass spectrometer. The ratios are normalized to National Bureau of Standard common lead standard. The lead isotopic compositions along with computed model ages and μ values of three galena. specimens from Cu-bearing quartz veins are given in Table 1 and are plotted in conventional diagrams of $^{206}Pb/^{204}Pb$ vs $^{208}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ (Fig.2). The data plot very close to the evolutionary growth curve of Stacey and Kramers (1975). There is very less variation in lead isotopic composition where $^{206}Pb/^{204}Pb$ is ranging from 18.728 to 18.793; $^{208}Pb/^{204}Pb$ from 15.658 to 15.728 and $^{208}Pb/^{204}Pb$ from 39.040 to 39.285. These leads are considered to be radiogenic.

As we have three isotopic compositions and these are not plotting on a single line, therefore, the best fit line with a slope (R) of 0.802 has been determined in a plot of $^{206}Pb/^{204}Pb$ vs $^{207}Pb/^{204}Pb$. This anomalous line (slope) can be caused by the addition of varying amounts of radiogenic Pb, derived from U-Th-bearing minerals in the crust, to ordinary lead (Faure,1986). If this line is considered to be the true secondary isochron, then the calculated 3443 Ma (t_2) could be the instant in the past when the decay of U isotope produced radiogenic Pb having the $^{207}Pb/^{206}Pb$ ratio equal to the slope of anomalous Pb line.

TABLE 1. LEAD ISOTOPIC COMPOSITION AND THEIR COMPUTED MODEL AGES OF GALENA FROM Cu-BEARING QUARTZ VEINS OF GAWUCH FORMATION

S.No.	206Pb/204Pb	207Pb/204Pb	208Pb/204Pb	Model age (Ma)	μ
Tz5	18.79	15.73	39.28	140.66	10.01
Tz8	18.78	15.68	39.14	66.42	9.98
Tz203	18.73	15.66	39.04	42.89	9.86
Average	18.77	15.69	39.15	83.45	9.95

Model ages and μ values are according to Stacey and Kramers (1975).

The model ages (Table 1), calculated by the two stage model of Stacey and Kramers (1975), yield wide range (42 to 140 Ma) with μ values of 9.89 to 10.01 (Table 1). This could be considered as model age for the mineralization. The time span ranging from 42 to 140 Ma (average 83 Ma) is the time when Pb for Drosh-Shishi Cu-mineralization was separated from its source. In terms of the general plumbotectonic model of Doe and Zartman (1979) and Zartman and Doe (1981) the lead isotopic data plot between the continental crust and orogeny (Fig. 4 & 5) indicating that the studied galena may be characterized as containing an important contribution of lead from radiogenic source (i.e. upper continental crust component) and may also have relation with orogeny.

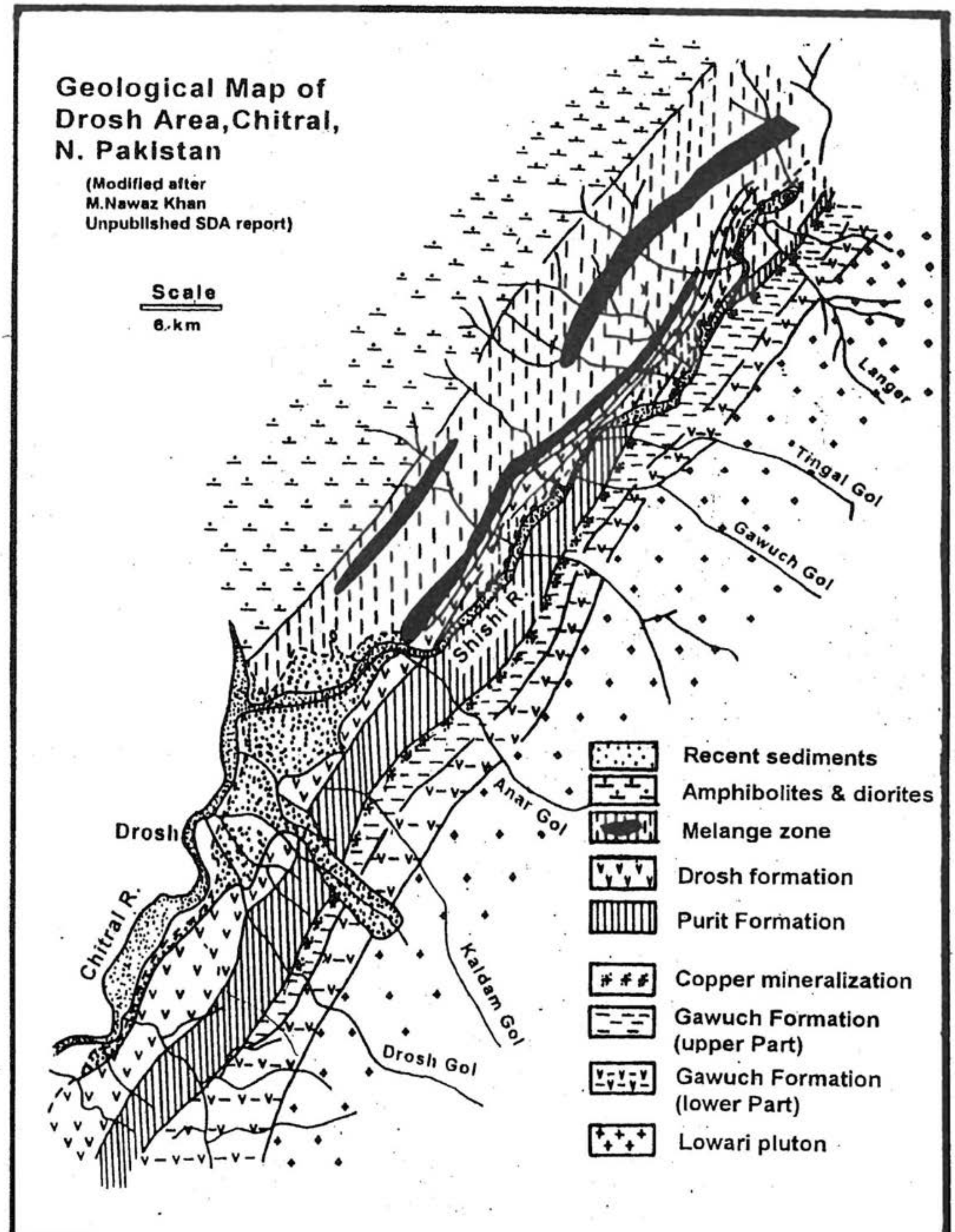

Fig. 1. Geological map of Drosh-Shishi area, Chitral, N. Pakistan.

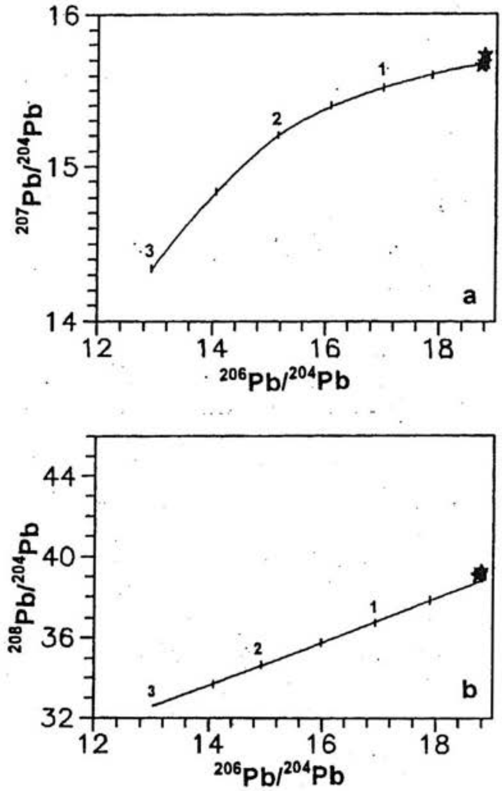

Fig. 2. Lead isotope ratio diagrams of galenas from the quartz veins of Gawuch Formation. Growth curve is after Stacey and Kramers (1975).

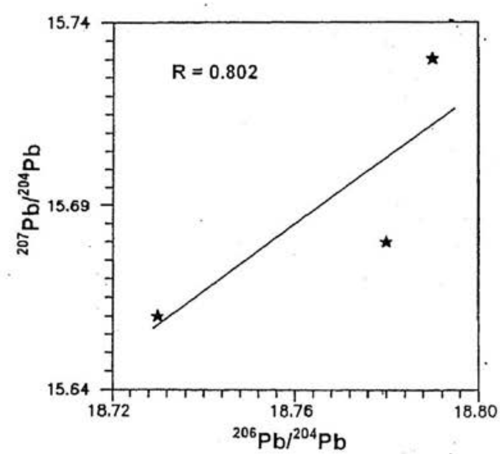

Fig. 3. $^{206}Pb/^{204}Pb$ vs $^{207}Pb/^{204}Pb$ diagram for the galenas from quartz veins of Gawuch Formation.

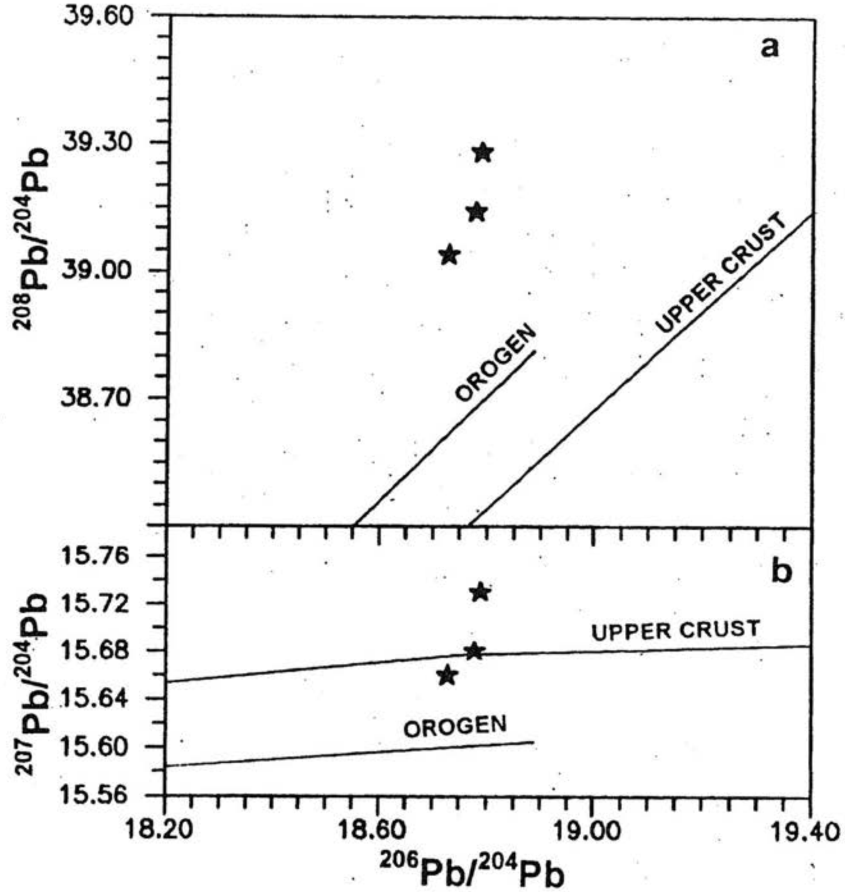

Fig. 4. Lead isotopic ratios of galenas from quartz veins of Gawuch Formation in relation to the growth curves of plumbotectonic model of Doe and Zartman (1979).

The Pb-isotope composition of galena from the cu-bearing quartz vein in the Gawuch Formation are compared with various types of veins and other deposits elsewhere in the world (Fig. 6). These diagrams also show the average growth curves of plumbotectonic modal of Doe and Zartman (1979) for the most significant reservoirs including the mantle, orogene, lower and upper crust. There is very close similarity of isotopic composition of the studied galena with that of Rossie-Type veins of New York (Ayuso et al., 1987) and Ontario (Fletcher and Farquhar, 1982) in both the $^{207}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ diagram (Fig. 6a & b). Compare to the lead isotope composition of galena from Balmet-Edwards district (Fletcher and Farquhar, 1982), the studied galenas are clearly more radiogenic. These are, however, less radiogenic than the Mississippi Valley-type deposits (Doe and Delevaux, 1972; Heyl et al., 1966) and the Laisvall-type sandstone - hosted lead - zinc deposits of Sweden (Richard et al., 1981). The studied galenas are also more radiogenic relative to the conformable massive sulfide deposits elsewhere (LeCouteur, 1973; Fletcher, 1979; Fletcher and Farquhar, 1982; Koeppel, 1980; Gulson et al., 1983; Gulson, 1984 & 1985; Deb et al., 1989; Shah et al., 1992). It is clear from these diagrams (Fig, 6a & b) that the galenas from Gawuch Formation have similar isotopic composition as that of Rossie -Type veins of USA and Canada.

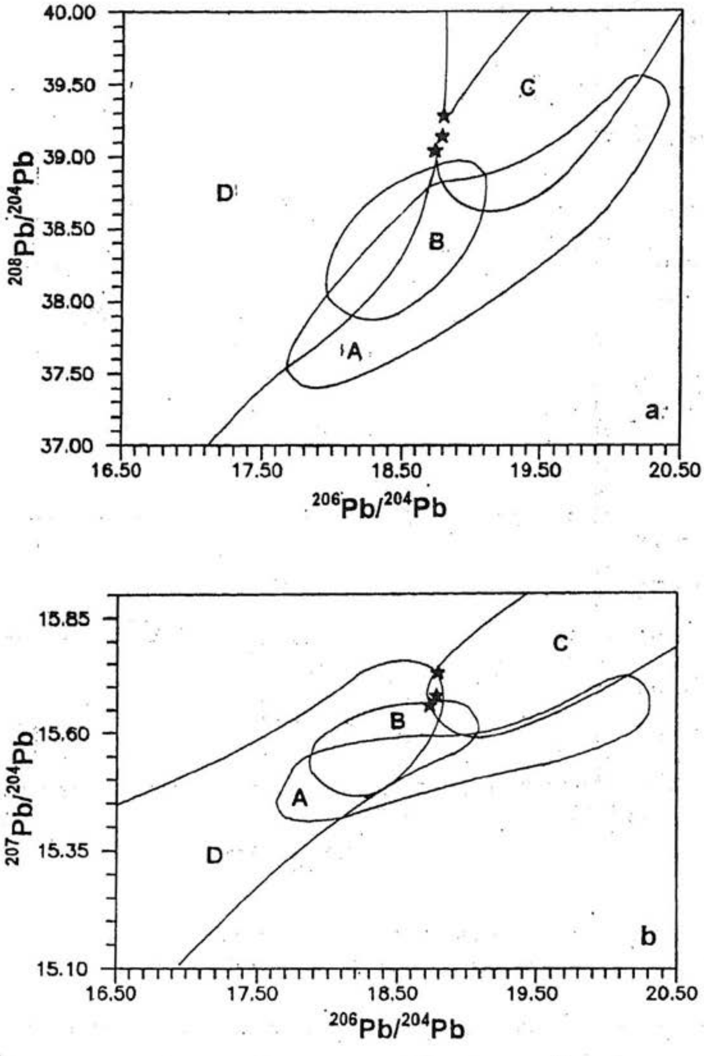

Fig. 5. Plots of lead isotopic ratios for the galenas form quartz veins of Gawuch Formation. Fields for A = mantle, B = orogene, C = upper crust and D = lower crust are after Zartman and Doe (1981).

The geological setting of Cu-mineralization in the Gawuch Formation is primarily governed by intrusion of diorite-granodiorite sill-like bodies in the pre-existing sequence of volcanics and sediments, hereby called Drosh group. According to stratigraphic scheme of Pudsey et al. (1985), the Drosh group is divisible into Gawuch Formation at the base, Purit formation at the intermediate levels and Drosh formation on the Top. The diorite, granodiorite sills intrusive into the Gowuch formation, are probably related with the main Kohistan batholith (Lowari pluton) exposed at the Lowari Pass. Although there is no direct control on the age of the diorite-granodiorite sills in the Gawuch formation, the Lowari pluton has, however, been radiometrically dated to be 40-48 Ma (Ar40-Ar39, Zeitler, 1985; Treloar et al., 1989).

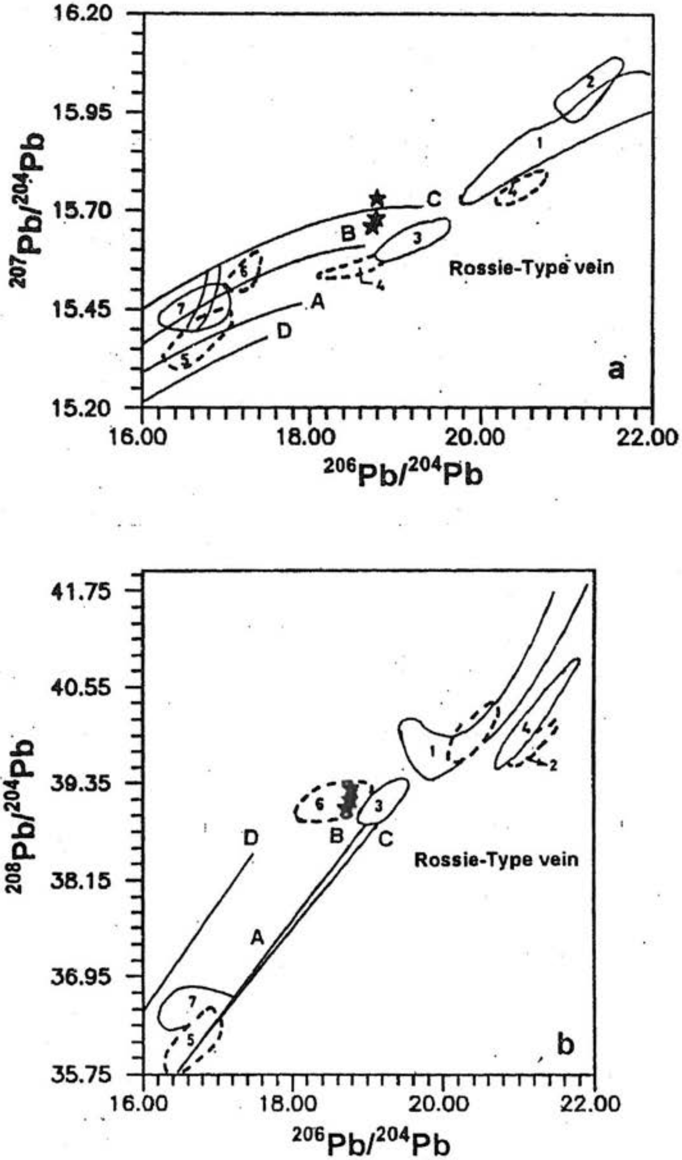

Fig. 6. Plots of $^{207}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ vs $^{208}Pb/^{204}Pb$ for galenas from quartz veins of Gawuch Formation. Various fields for other deposits are also shown.
1 = Mississippi Valley Type deposits (Central Missouri), Doe and Delevaux (1972).

The Pb isotopic compositions for galenas from copper-bearing quartz veins in Gawuch Formation yield wide range of age (42 to 140 Ma) with μ values of 9.86 to 10.01 (Table 1). This could be assigned as the model age for mineralization and could be considered as the upper limit of the age of copper mineralization in Gawuch Formation. This time spane (42-140 Ma; mean 83 Ma) is the time when Pb for the studied galenas was separated from its source.

According to plumbotectonic model, the studied galenas are characterized as containing an important contribution of lead from a radiogenic source. The minimum age (i.e. 42 Ma) is in close agreement with Ar-Ar age (40-48 Ma Zeitler 1985; Treloar et al., 1989) of the Lowari plutons which is considered to be the source of the hydrothermal solutions responsible for the copper mineralization in Gawuch Formation. The model ages of 80 and 140 Ma, however, indicate that the galenas from Gawuch Formation have also incorporated Pb from an older source. There could be two possibilities for the origin of old age of Pb; first if we consider that much of the Kohistan batholith would have itself formed from partial melting of the early arc lithologies in Kohistan, the older Pb component in studied galenas might be from early arc volcanics or the pelegic sediments of ocean crust of the Neo-Tethys (Jurassic age). The other possibility is that the radiogenic Pb component of the studied galenas might have been contributed from Pb source in the Indian plate. The magma generated at the time of 40-48 Ma for Lowari pluton at least had some contributions from the subducting Indian-plate continental crust, even in the form of dehydration fluids.

CONCLUSIONS

Hydrothermal copper mineralization in Drosh-Shishi area is present in the upper parts of Gawuch Formation and is generally confined to the diorite/granodiorite intrusions and associated quartz veins. The lead Isotopic compositions of galenas from the quartz veins yield model ages of 42 to 140 Ma for Copper mineralization in Drosh- Shishi area. The minimum age of the mineralization is in close agreement with that of Lowari pluton which could be the possible source of hydrothermal solution responsible for the copper mineralization. The lead in galena is radiogenic and may have been derived from arc volcanics or pelagic sediments of the Néo-Tethys or continental crust of Indian plate.

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