DISCUSSION

MALANJKHAND COPPER DEPOSIT, INDIA: IS IT NOT A PORPHYRY TYPE?

by D. B. Sikka and C. E. Nehru. Jour. Geol. Soc. India, 2002, v.59(4), pp.339-362.

Rajesh K. Vishwakarma, Investigation Division, NMDC Ltd., Masab Tank, Hyderabad - 500 028, comments:

It seems the merit of the above paper suffers due to some untenable and inaccurate interpretations of the published results. The principal discrepancies, given below, warrant attention, because the discussion indicates lode-type origin without granitoid affiliation and not a porphyry-type.

Quartz Stockwork

Sikka and Nehru (2002, p.349) have misstated Vishwakarma's (2001) reference against this: "the stock work is absent (eroded ?)". Also, Sikka and Nehru's repeated corroboration of stockwork does not take into account the general understanding of the stockwork, which is widely known to occur in a large-scale ramifying and dichotomizing series of fissures particularly in rich deposits. At Malanjkhand one can only recognize highly sheared system of parallel to subparallel veins (e.g. Bhargava et al. 1999) and also the zone of parallel or small-scale cross-cutting mineralized quartz veins (e.g. Pal, 2001). But neither these are multidirectional in disposition nor these are developed to an extent by which such a feature can be termed stockwork *sensu stricto*. Plausibly for this reason, Pal (2001) could not provide field evidence of large-scale-multidirectional feature in order to respond to a viewpoint (Vishwakarma, 2001) related to the extremely small-scale nature of cross-cutting quartz vein having no link with the stockwork.

Wallrock Alteration and Super-large Mineralization

The statement that "any type of alteration associated with potassium metasomatism, chloritization, ... involves the release of quartz" (Sikka and Nehru, 2002, p.345) is applied for the mineralized quartz vein at Malanjkhand, and thus it is questionable and unacceptable in view of the established fact, rendered both by the proponents of porphyry-type (Bhargawa and Pal, 2000; Pal, 2001) and lode-type settings (Rai and Venkatesh, 1993; Panigrahi and Mookherjee, 1998; Vishwakarma, 2001 and 2001a), that the effect of hydrothermal alteration is not intense and pervasive in nature. Even Sikka and Nehru (1997, p.248) earlier reported the localized nature of potassic alteration. Additionally, it may be recalled that Sarkar et al. (1996) have also not opined Malanjkhand as porphyry-type by virtue of intense silicification. Places of selectively pervasive alteration may also be attributed to alteration from silica-rich hydrothermal ore-fluid (Vishwakarma, 2001a), metamorphism or even the intrusion of metabasites cross-cutting ore body. Clearly, a primary control on the ultimate magnitude of the deposit will be the size of the hydrothermally altered rocks; these rocks are too small volumetrically to account for the comparatively giant nature of metal and quartz concentration.

Arc Volcanism

Study of local geology (Sikka and Nehru,2002,p.341) suggests that the Malanjkhand granitoid is the main rock type exposed in the mine area and surrounding country. As rocks typical of arc volcanism (spatially and temporally related to Malanjkhand granitoid and ore deposition) are totally absent, the deposit cannot be termed porphyry type. The discussion part of the regional geologic and tectonic setting (Sikka and Nehru,2002,p.355) too has failed to identify arc volcanism penecontemporaneous with calc-alkaline plutonism and ore mineralization. After all, arc volcanism is one of the environs associated with the porphyry deposits (Vishwakarma, 2001; Pal, 2001).

Mineralization

Sikka and Nehru (2002, p.351) conjectured that "Vishwakarma's opinion (2001) on the high temperature origin of the ores has a bearing on the lode-type mineralization, which is based on wrong and incorrect interpretation of published account". This is a baseless criticism since Vishwakarma (2001, 2001a) proposed lode-type mineralization collectively on the basis of high temperature origin of some of the ore minerals that occur in the same geologic environment of the Malanjkhand deposit (e.g.,the early ferrous metals forming at much higher temperature than the significantly low temperature differentiated microgranite), wide gap between the age of mineralization and granitoid emplacement and also the

striking difference between Pb-isotopic signatures of granitoid and ore minerals.

Pb- and S-Isotopes

Pb-isotopes:

Sikka and Nehru (2002) state that Pal (2001) has successfully responded to Vishwakarma's (2001) arguments against the porphypry classification of the Malanjkhand deposit. This is as misleading as Pal's (2001) following intuitive remarks on the acceptance of Pb-isotopic study:

A. The very low Pb content in ore and host rock may not give correct Pb isotopic age particularly when the system has been disturbed by younger deformational event (Pal, 2001), and
B. Since Pb content in K-feldspar rich pink granitoid, aplite and quartz vein shows the same value as the mill feed ore, high radiogenic Pb in ore and low in granite Pb are of no significance (Pal, 2001).

The first one cannot be given credence due to: (A) a recent study (Stendal and Frei, 2000) gives fair impression that Pb isotopic signatures of ore minerals (pyrite, magnetite) and quartz vein provide unique constraints on metallogenesis. Thus, low Pb in ore is of little significance, because Pb has high atomic mass and is insensitive to natural mass-dependent fractionation processes. Hence, it is strongly believed that under conditions of deformation Pb-Pb isotopes are much more resistant to resetting than Rb-Sr and K-Ar isotopes. (*also see*: Schleicher et al. 1997).

The second point (B) is totally unscientific. Likewise, Sikka and Nehru (2002) too have negated the importance of Pb-isotopes by stating that "uraninite and thorite are present in Malanjkhand (Sikka and Nehru, 1998) which would affect the Pb-isotopic ratios". After evaluation of the following, it is not clear, why Sikka and Nehru (2002) preferred such information?

Sikka and Nehru (1998) considered uraninite as one of the principal ore minerals, and in this study there is no report of thorite. Uraninite has only been reported in trace amount by Tripathti (1979),which cannot be ascribed as 'principal' ore mineral. Recently, the conclusion part of Sikka and Nehru's (2002) paper does not also recognize presence of uraninite on the basis of their extensive petrographic study.

Furthermore, it is totally disagreeable that uraninite/ thorite have a bearing on the highly radiogenic ore Pb behaviour at Malanjkhand, because these minerals,if any, have not changed the presently observed less radiogenic granitoid Pb to enable possible correlation with the exceptionally high radiogenic ore Pb.

Sulphur isotopes

$\delta^{34}S$ values of -3.8 to +2.9 ‰ have been utilized to propound porphyry genesis (Sikka and Nehru, 2002). This is an improper approach of study, for the values given are in no way characteristic of only porphyry-type deposits. Other magmatic and sedimentary deposits (with indirect magmatic sulphur sources or even without magmatic component) may also preserve the above narrow range of $\delta^{34}S$ value.

Granitoid Trace Elements

An impression is given through the study of Sikka and Nehru (2002 p.354) that trace element data on the Malanjkhand granitoid is published in Sikka and Nehru (1997), and the same has been used in the Pearce discriminant diagram in order to contemplate presence of volcanic arc granites in Malanjkhand. All this is not convincing because there is no such data as claimed by Sikka and Nehru (2002) or Sikka and Nehru (1997). Without producing any diagram the latter publication simply contains information like "Ta *vs* Yb and Rb *vs* (Yb+Ta) and Rb *vs* (Y+Nb) plots for the Malanjkhand granitoids on the discrimanant diagrams by Pearce et al. (1984) fall within the field of volcanic arc granites" which is opined by Nehru (unpublished).

Polymict Metaconglomerate

The observation (Sikka and Nehru, 2002, p.341; Pal, 2001) of the presence of conglomerate containing granitic pebbles and boulders is highly questionable. These would have in fact insignificant stratigraphic relationship with the polymict metaconglomerate immediately overlying the surface of unconformity atop granitoid and ore body. Earlier, Sikka (1989,p.494) himself advocated that the conglomerate, at the contact of the Chilpi Group and Malanjkhand granitic rock, "is made up of pebbles, cobbles and boulders of quartzite, chert, jasper, quartz, and slate".

D.B. Sikka, Cabinet-Conseil en Geologic Miniere Sikka ENR, 2108, 3463 Rue Ste. Famille, Montreal Canada, H@X 2K7 and **C.E. Nehru**, Department of Geology, Brooklyn College of the City University of New York, Brooklyn, NY - 11210, USA, reply:

Many of these comments have already been aired by Vishwakarma (2001, pp. 554-556) in his discussion of

Bhargava and Pal's (2000) paper and generally answered by Pal (2001, p.556-557). Our response to his recent comments are as follows:

Quartz Stockwork

Vishwakarma (2001a) states that the mineralization is of 'lode' type. He insists that the extremely small-scale nature of the cross-cutting veinlets have no link with the stockwork.

"*Lode*" as defined by an act of the United States Congress around 1870, is a mining term and has definite dimensions. *Lode* is defined by the American Geological Institute's Glossary of Geology (Jackson, 1997) as " a mineral deposit consisting of a zone of veins, veinlets, disseminations, or planar breccias; a mineral deposit in consolidated rock as opposed to placer deposit". Stockwork is defined as "a mineral deposit consisting of a three-dimensional network of planar to irregular veinlets closely enough spaced that the whole mass can be mined". The mineralization at Malanjkhand as described in Petruk and Sikka (1987), Sikka (1989), Sikka and Nehru (1997, 2002) and Bhargava and Pal (1999, 2000) all conform to the above definition and are used in accordance to the normal international usage of the term.

Vishwakarma has been asserting that the mineralization at Malanjkhand is of "lode" type and that there is no stockwork. We would like to draw attention to the geological cross-section of the Malanjkhand copper deposit published by Vishwakarma (2001a; Fig.2; p.93). This is the same published earlier by Panigrahi and Mookherjee (1997; Fig.3; p.135). Vishwakarma has not even corrected the 'typographic error of 'weatherhead zone' for 'weathered zone' in the legend to the figure reproduced by him. Hence, Vishwakarma cannot attribute this cross-section to Sikka (1989). The cross-section published by Panigrahi and Mookherjee (1997) is not very excat, a fact acceded to by them (Panigrahi and Mookherjee, 1998).

In this cross-section of Vishwakarma (2001a, Fig.2; p.93) the pit-outline encloses pink granitoid cut by aplite and a dolerite dyke with very little of the quartz-reef and ore being shown. If this were to be correct, HCL has been mining for the last20 years, about 20 million tonnes of waste rock to reach the ore-zone! The inaccuracy of the above statement is obvious.

Vishwakarma complains that Pal (2001) failed to respond to his (2001) viewpoint related to extremely small-scale nature of quartz veins having no links with the stockwork. But Vishwakarma (2001a, p. 94) states that he has thoroughly examined various aspects of Malanjkhand deposit in the field, but he fails to provide any field evidence to counteract Bhargava et al. (1999) and Pal (2000). Incidently, "Bhargawa" is wrongly spelled and Pal (2000), as quoted in Vishwakarma's comments on our paper, does not exist.

Contrary to his current comment on stockwork, Vishwakarma (2000, p.11) himself stated, "The primary Cu ore generally occurs in the form of stockwork and dissemination". Further, according to Vishwakarma (2001a, p.94) "primary copper ore occurs as stringer-disseminated-and massive - type in quartz veins". Note that stringer ore is stockwork (Bates and Jackson, 1989; Sikka and Nehru, 2002). The nature of stockwork or stringer type ore is given by Rai and Venkatesh (1993, Plate 2b, p. 294), a reference cited by our critic in his (2001a) paper. In view of Vishwakarma's (2000 and 2001a) admission of the presence of stockwork at Malanjkhand, his contention that mineralization is of the lode type and his comments on Pal (2001) that he did not respond to his (Vishwakarma's) viewpoint is incomprehensible to say the least.

Wallrock Alteration and Super-large Mineralization

Vishwakarma contends that hydrothermal alteration is not intensive and pervasive. For one who has failed to identify the "*lode*" (75-80 m wide zone) and the mineralized zone in the pit (which is about 264 m wide), we wonder how he was able to determine the nature of wall rock alteration. The wall rock alteration studies require detailed microscopic work and X-ray data, which he has not provided. It is not that wall rock alteration is not intensive or pervasive, but it has not been properly mapped. Sikka (1982, 1984) had identified various types of wall rock alterations, i.e. argillization, propilitization, sausseritization, chloritization, kaolinization, feldspathization and silicification and recommended these to be mapped. Early work was done by Seetharam (1981) on samples, which could be easily located on maps. Several agencies were involved in the exploration work at Malanjkhand. Some of the geologists lacked interest in performing detailed studies and sometimes details that were necessary were not mapped. Rai and Venkatesh (1990, 1993), Ramanathan et al. (1990), Sarkar et al. (1996), Panigrahi et al. (1991), Panigrahi and Mookherjee (1997; 1998), did useful work on mineralization and wall rock alteration. But none of these studies resulted in any maps of wall rock alteration zones. These studies are of limited use, because we cannot define an alteration model and draw conclusions. The only maps on the wall rock alteration zones, produced on the basis of detailed mineralogical and wall rock alteration data are by Bhargava and Pal (1999). Pal's (2001, p.553) statement summarizes years of experience by the resident geologists at

Malanjkhand: "These observations undoubtedly prove that there is no ambiguity regarding wall rock alterations and alteration mineral assemblages observed by the present authors". Vishwakarma's statement that the wall rock alteration at Malanjkhand is not pervasive is untenable.

Arc Volcanism

We do not agree with Vishwakarma's comments on arc volcanism. Sikka and Nehru's (2002) paper does not focus on the petrochemistry and petrogenesis of Malanjkhand granitoids. In view of Nehru and Sikka's forthcoming paper, which is in preparation on these topics, we adopted the normal practice to leave it as *Nehru unpublished.* In support of the arc volcanism association, we quote "By whatever name one may call them, it is certain that these volcanic rocks have followed and accompanied the granodiorite batholith of Malanjkhand-Taregaon", Tripathi (1979, p. 165). Further Sarkar et al. (1996, p. 421-422) wrote "The geochemistry of dacitic-andesitic rocks of Malanjkhand (unpublished data) closely resembles the plutonic/hypabyssal rocks of the area, suggesting them to be co-genetic. .... Petrography and the bulk geochemistry of the rocks discussed above are consistent with an arc model".

Mineralization

"Sikka and Nehru (2002, p.351) conjectured that Vishwakarma's (2001) opinion on the high temperature origin of the ores has a bearing on the lode-type mineralization, which is based on wrong and incorrect interpretation of the published account". We maintain our comments for reasons given.

Vishwakarma (2001a) insists that pyrrhotite is not observed in the ore microscopic examination of samples. Yet he refers to Sikka and Nehru (1998) in his references. Sikka and Nehru (1998; 2002) have noted the presence of pyrrhotite in Malanjkhand. Rai and Vekatesh (1993, p. 293, a reference cited by Vishwakarma 2001, 2001a) and Singh (1996) have also identified the presence of pyrrhotite. In view of the foregoing, Vishwakarma's (2001, p. 555) opinion that the ores at Malanjkhand are of high temperatures origin, *which* has a bearing on his conclusion that the mineralization is of the lode type, is based on wrong and incorrect interpretation of published data.

Vishwakarma (2001, p.556) concludes that "Malanjkhand is not an intrusion related deposit, the role of sedimentary processes akin to exhalative activity due to sea water convection in the spreading ridge environment may hold good to account for metallogeny". Vishwakarma provides no basic information, i.e. chemical, mineralogical, petrographical, geochemical maps to support his views. "SEDEX" (sedimentary exhalative) deposits form in a sedimentary basin by the submarine venting of hydrothermal fluids and sphalerite and galena are principal ore minerals (Lydon, 1996, p. 130). Based on data from 62 deposits (excluding Howard Pass), the size averages 41.3 MT with 6.8% Zn, 3.5% Pb and 50 g/t Ag (Lydon, 1996 p. 130). On the other hand Malanjkhand contains 789 MT, averaging 0.83% Cu, 0.004 wt.% Mo, 0.2 g/t Au and 6 g/t Ag; also 7.5 MT of oxide ore averaging 0.8% Cu (Sikka 1989; Sikka and Nehru 1997, 2002). In view of this, Malanjkhand does not fit into SEDEX type deposits.

According to Vishwakarma (2001, p. 555) "Sarkar et al. (1996) have not identified Malanjkhand as a porphyry deposit. They have clearly stated in the very first line of the abstract that Malanjkhand is a lode-type copper (-molybdenite) deposit". On the contrary Sarkar et al. (1997, p. 622) " ... our conclusion, based on the available information from the petrology of the host rock, hydrothermal alteration assemblages, ore mineral associations, fluid inclusions and stable isotopes, that the Malanjkhand deposit has similarities with Phanerozoic porphyry systems still remains".

Pb and S Isotopes

Vishwakarma questions the statement of Sikka and Nehru (2002) that Pal (2001) has successfully responded to Vishwakarama (2001) arguments against the porphyry classification of the Malanjkhand deposit. He considers this statement misleading because of his Pb-isotopic study. We maintain that Pal (2001) generally responded to Vishwakrama's comments against porphyry copper origin. We will respond to his ideas on the presence of uraninite and thorite and Pb-isotopes below.

Pb - Isotopes

According to Vishwakarma (2001, 2001a) petrography of all the analysed samples did not reveal the presence of U-rich minerals, which can affect lead isotopic composition of everything including ores, quartz veins as well as granitic rocks. Absence of U-rich minerals was confirmed by GM count at Bhabha Atomic Research Center, Hyderabad. According to Vishwakarma uraninite has only been reported in trace amounts by Tripathi (1979). It may be mentioned that Rai and Venkatesh (1993, p. 294), a reference cited by Vishwakarma, have also reported uraninite. This contradicts his statements that there is no uraninite. Apatite can carry uranium.

We do not understand Vishwakarma's recent comment

that we are preferring inaccurate interpretation of published result. Malanjkhand area was covered by airborne gamma ray spectrometry in 1971/72 by BRGM AMSE, GSI and later by the Atomic Minerals Division. Gamma ray maps of total count, thorium and uranium families, and K^{40} are available. The uranium and thorium family maps (BRGM) show, (in places) anomalous values indicating the presence of uranium and thorium minerals. It is a well-known fact that uraninite is a principal ore mineral of uranium even if is found only in trace amount. The knowledge of existence of trace minerals can lead to major discoveries. Geogases such as CO_2, N_2, CH_4, and H_2 and minor quantities of He, Ar, Rn, Hg, H_2S, SO_2, I, Br, Cl, migrate towards the surface in gaseous form as microbubbles and in solution. Gases encapsulate Rn (Radon), liquid hydrocarbons and other trace elements, such as As, Ag, Ba, Cd, Ce, Co, Cr, Cu, Ga, Ge, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ti, Th, U, V, W, Y, Zn and carry them to surface from great depths from underlying rocks through faults and fractures to the surface (Sikka and Shives, 2002a and 2002b). The gases do not know if the lead is radiogenic or not.

Vishwakarma questions why Sikka and Nehru (2002) have not listed uraninite in their conclusions. Since Sikka and Nehru (2002) were focused on a huge forest and not a single leaf on a tree, did not consider it necessary to list in their conclusions. Further, Vishwakarma considers the presence of uraninite and thorite has no bearing on the high radiogenic Pb, at Malanjkhand. We consider that one does not need ore grade material; the presence of these minerals in faults, fractures and fissures can affect Pb isotope ratios. Also, the highly radiogenic Pb component in the ore is almost certainly due to the presence of uraninite in the later. In view of this we consider his statements as unacceptable.

Sulphur Isotopes

Suphfur isotopes are one of the tools to identify the origin of sulphur. The data given in Table 1 by Sikka and Nehru (2002, Table 1) was to indicate that sulphur is of magmatic origin. Vishwakarma (2001a, p. 96, Table 2) has reported $\delta^{34}S$ values for a number of samples of chalcopyrite (5), pyrite (2), and molybdenite (2). The isotopic values for chalcopyrite (samples 1, 2 and 3), pyrite (samples 7 and 9). Molybdenite (sample 6) respectively average + 0.29 ‰, + 0.255 ‰ and + 0.14 ‰. We omit the other data because the samples are suspect. The overall reproducibility reported by Vishwakarma (2001a, p. 95) is ±0.50 ‰. $\delta^{34}S$ data of 6 out 9 samples lie below ±0.50 ‰. Hence this data are useless. The purity of chalcopyrite and molybdenite would affect the $\delta^{34}S$ values. The values for two samples of chalcopyrite and one sample of molybdenite are suspect.

Granitoid and Trace Elements

Vishwakarma questions the use of unpublished data. Vishwakarma (2001, p. 555 and 2001a, p. 95) himself has made statements like this in the past (e.g. Vishwakarma *in press*; Vishwakarma and Frei *in preparation* p. 95 without giving any real data). Schleicher et al. (1997, p. 271), (a reference given at the end of Vishwakarma's recent discussion of our paper), have stated that "This is in agreement with the Sr and Nd isotopic data (... our own unpublished data)" !. We do not understand what is the problem in our mentioning our unpublished data, which is a normal practice.

Polymict Metaconglomerate

Vishwakarma states that Sikka (1989) was advocating conglomerate horizon without granitic pebbles. Now, he seems to wonder *Why granitic pebbles now*? There are granitic pebbles, cobbles and boulders in the polymict conglomerate overlying the Malanjkhand granitoid. These are exposed in a number of benches in the south-western part of the mine area. With the opening of new benches, new exposures are available. These have been observed above the granitoid surface by (Pal, 2001) and Sikka and Nehru (2002). We find that the conglomerate is fresh and is not metamorphosed. In 1989 these were not exposed.

Concluding Statements

The characteristic features of Malanjkhand porphyry type deposit are large tonnage, low grade, simple mineralogy, presence of stockwork, association with I type granitoids, nature of wall rock alteration mineral assemblages, zones of oxidation and secondary enrichment, sulphur isotopes. These should be considered together as a whole and not individually. Vishwakarma and others who argue against the porphyry type deposit for Malanjkhand are looking at individual aspects associated with the deposit and not looking at them collectively.

Dr. Roy Woodall, Director of Exploration, Western Mining Corporation, in his 4th Mawson lecture (1984) entitled "Limited vision: A personal experience of mining geology and scientific mineral exploration" delivered at the Seventh Australian Geological Congress describes how one could misinterpret something if one were not looking at the whole picture. He quotes the well known poem of the 'Six Blind Men and the Elephant', which is apt in this context.

We welcome scientific criticism that would improve our publication. This has to be based on facts and critic's own experience. Some of the references cited by Vishwakarma contradict his own statements. Most of the criticisms of Vishwakarma are without any substantial basic data to support his comments and observations.

References

BATES, R.L. and JACKSON, J.A. (1987) Glossary of Geology. American Geological Institute, 3rd Edn. 788p.

BHARGAVA, M. and PAL, A.B. (1999) Anatomy of a Porphyry Copper Deposit - Malanjkhand, Madhya Pradesh. Jour. Geol. Soc. India, v.53, pp.675-691.

BHARGAVA, M., PAL, A.B. and SINDHUPE, G.L. (1999) Cu-Mo-Au metallogeny related to Proterozoic magmatism in Malanjkhand region, Madhya Pradesh. Proc. National Seminar on Geology and Mineral Wealth of the Precambrians of Central India, Jabalpur, pp.29-30 (Abs).

BHARGAVA, M. and PAL, A.B. (2000) Cu-Mo-Au Metallogeny associated with Proterozoic Tectono-magmatism in Malanjkhand porphyry copper District, Madhya Pradesh. Jour. Geol. Soc. India. v.56, pp. 395-413.

JACKSON, JULIA, A. (1997) Glossary of Geology, American Geological Institute, 4th Edn. 795p.

LYDON J.W. (1996) Sedimentary exhalative sulfide deposits; in Geology of Canadian Mineral Deposits Types *In:* O.P. Eckstrand, W.D. Sinclair, and R.I.Thorpe (Eds.), Geological Survey of Canada, Geology of Canada, No. 8, pp. 130-152 (Also Geological Society of America, Geology of North America, V.P.1).

PAL, A.B. (2001) Cu-Mo-Au Metallogeny associated with Proterozoic Tectono-magmatism in Malanjkhand porphyry copper District, Madhya Pradesh – a reply. Jour. Geol. Soc. India, v.57, pp.556-558.

PANIGRAHI, M.K., MISRA, B. and MOOKHERJEE, A. (1991) Ore mineralogy and fluid inclusion characteristics of different ore associations from Malanjkhand copper deposit. M.P. (India). Jour. Geol. Soc. India, v.37, pp.239-256.

PANIGRAHI, M.K. and MOOKHERJEE, A. (1997) The Malanjkhand copper (+molybdenum) deposit, India: mineralization from a low temperature ore-fluid of granitoid affiliation. Mineral. Deposita, v.32, pp.133-148.

PANIGRAHI, M.K. and MOOKHERJEE, A. (1998) The Malanjkhand copper (+molybdenum) deposit, India: mineralization from a low temperature ore-fluid of granitoid affiliation – a reply. Mineral.Deposita, v.33, pp.430-432.

PETRUK, W. and SIKKA, D.B. (1987) The formation of oxidised copper minerals at the Malanjkhand porphyry copper deposit in India, and implications on metallurgy. *In:* A.H. Vassiliou, D.M. Hausen, and D.J.T. Carson (Eds.), Process MineralogyVII. Warrendale, P.A.: The Metallurgical Society, pp. 403-420.

RAI, K.L. and VENKATESH, A.S. ((1990) Malanjkhand copper deposit - A petrologiocal and geochemical appraisal. Geol. Surv. India. Spec. Publ. No 28, pp.563-584.

RAI, K.L. and VENKATESH, A.S. (1993) Geologic setting and nature of copper and molybdenum in the intercontinental acid magmatic regime of Malanjkhand, Central India. Resource Geology Special Issue no 15, pp.282-297.

RAMANATHAN, A., BAGCHI, J., PANCHAPAKESSAN, V., and SAHU, B.K. (1990) Sulfide minearlization at Malanjkhand – a study. Geol. Surv. India Spec. Publ., v.28, pp.585-598.

SARKAR, S.C., KABIRAJ, S., BHATTACHARYA, S. and PAL, A.B., (1996) Nature, Origin and evolution of the granitoid-hosted early Proterozoic copper - molybdenum mineralization at Malanjkhand, Central India. Mineral.Deposita, v.31, pp.419-431.

SARKAR, S.C., KABIRAJ, S, BHATTACHARYA, S. and PAL, A.B. (1997) Reply to Changkakoti's comment on Nature, Origin and evolution of the granitoid-hosted early Proterozoic copper - molybdenum mineralization at Malanjkhand, Central India. Mineral.Deposita, v.32, pp.622.

SCHLEICHER, H., TODT, W., VILADKAR, S.G. and SCHMIDT, F (1997) Pb/Pb determinations on the Newania and Sevattur carbonatites of India: evidence for multistage histories. Chem.Geology, v.140, pp.261-273.

SEETHARAM (1981) Mineralogy and genesis of the copper sulfide deposit, Malanjkhand, Balaghat district. M.P. Unpublished Ph.D. thesis, Nagpur University, Nagpur.

SIKKA, D.B. (1982) Visit to copper complexes. Hindustan Copper Limited. Nov. 4-26, 1981. UNDP TOKTEN Report, Sikka and Associates Ltd. Nassau, Bahamas.

SIKKA, D.B. (1984) A feasibility study for setting up a mining, milling and 100,0000 TPY smelting refining complex based on Malanjkhand porphyry copper deposit, M.P. India. Company Report for Hindustan Copper Ltd. Sikka and Associates Ltd. Nassau, Bahamas.

SIKKA, D.B. (1989) Malanjkhand: Proterozoic porphyry copper deposit, M.P. India. Jour. Geol. Soc. India, v.34, pp.487-504.

SIKKA, D.B. and NEHRU, C.E. (1997) Review of Precambrian porphyry Cu ±Mo±Au deposits with special reference to Malanjkhand porphyry copper deposit, Madhya Pradesh, India. Jour. Geol. Soc. India, v.49, pp.239-288.

SIKKA, D.B. and NEHRU, C.E. (1998) Discussion on nature, origin and evolution of granitoid-hosted early Proterozoic copper - molybdenum mineralization at Malanjkhand, Central India. Mineral. Deposita, v.33, pp.524-530.

SIKKA, D.B., and NEHRU, C.E. (1998) Comment on the article by M.K. Panigrahi and A. Mookherjee: The Malanjkhand copper (+molybdenum) deposit, India: mineralization from a low temperature ore-fluid of granitoid affiliation, (Mineralium Deposita, v.32, pp.133-148.) Mineralium Deposita, v.33, pp.425-429.

SIKKA, D.B. and NEHRU, C.E. (2002) Malanjkhand copper deposit, India: Is it not a porphyry type? Jour. Geol. Soc. India, v.59, pp.339-362.

SIKKA, D.B. and SHIVES, R.B.K. (2002a) Radiometric Surveys of the Redwater Oil field, Alberta: Early exploration case histories suggest mechanisms for the development of Hydrocarbon - Related Geochemical Anomalies. *In:* D. Schumacher and L.A. LeSchack (Eds.), Surface exploration case histories. AAPG studies in geology No. 48 and SEG Geophysical References series No. 11 (*in press*).

SIKKA, D.B. and SHIVES, R.B.K. (2002b) Mechanisms to explain the formation of geochemical anomalies over oil fields in near surface hydrocarbon migration: mechanism and seepage rate. *In:* M.A. Abrams and J.K. Whelan (Eds.), Hedberg Conference, April 7-14, 2002 Vancouver, BC, Canada, AAPG studies in geology (*in press*).

SINGH, C.D.P. (1996) Geology, geochemistry and metallogenesis of Malanjkhand copper deposits, Madhya Pradesh. Tenth convention of Indian Geological Congress. Department of Applied Geology, Indian School of Mines, Dhandbad, pp.51-52 (abs.).

STENDAL, H and FREI, R (2000) Gold occurrences and lead isotopes in Ketilidian mobile belt, south Greenland. Trans. Instn. Min. Metall. (Sec.B), pp.6-13.

TRIPATHI, C. (1979) The Malanjkhand - Taregaon porphyry copper deposit. Geol. Surv. India Misc. Publ. No.34, pp.161-168.

VISHWAKARMA, R.K. (2000) Uranogenic laed isotope in Malanjkhand granitoid and Cu ore (Centreal India) pave the way for seminentgary origin: A new study. *In:* Harsh Bhu and Vinod Agarawal (Eds.), XIIth Indian Geological Congress, Profile of presentataions, p.11, (abs.).

VISWAKARMA, R.K. (2001) Discussion on Cu-Mo-Au Metallogeny associated with Proterozoic tectonic magmatism in Malanjkhand by M. Bhargava and A.B. Pal. Comments, Jour. Geol. Soc. India v. 57, p. 554-556.

VISHWAKARMA, R.K. (2001a). Isotopic characters of the Proterozoic Malanjkhand copper deposit, Central India: Implication for exhalative activity. Jour. Applied Geochemistry, v.3 (2), pp.91-103.

[A discussion on the genetic aspects of the Malanjkhand copper deposit has appeared earlier in the Journal (v.57, 2001, pp.550-558). The above discussion is the second on the topic and discerning readers will arrive at their own conclusions. Further discussion on the topic is closed. –Ed.]

SEDIMENTOLOGY AND SEQUENCE STRATIGRAPHY OF HYDROCARBON BEARING MANDAPETA PAYS: A BRAIDED FLUVIAL RESERVOIR, KRISHNA-GODAVARI BASIN by Yadagiri Kotha, Jour. Geol. Soc. India, v.60, no.3, pp.249-270.

V. K. Rao, Directorate General of Hydrocarbons, Ministry of Petroleum, New Delhi, comments:

The author has identified three genetic units, viz., channel lag, in-channel and over bank acrretions in the Mandapeta Formation and has described in detail the petrophysical and petrographic characteristics of hydrocarbon bearing sands.

However, no map/illustration showing geographic distribution of these genetic units/facies in the study area is included in the paper. Rather a time structure map on top of Mandapeta Formation is shown (Fig.3), which has less relevance to the main theme of the paper. Thus, the conclusion drawn by the author that the area to the west and southwest of Mandapeta (without Mandapeta location) is speculative and lacks credence in the absence of a descriptive/demonstrative map.

Yadagiri Kotha, ONGC, Jorhat, Assam replies:

At the outset I would like to thank Dr. V.K. Rao, Directorate General of Hydrocarbons, Ministry of Petroleum, New Delhi for evincing keen interest in my paper. Point-wise reply to the issues raised by Dr. Rao are as follows:

1. This is first ever integrated sedimentological analyses of the complex and the oldest petroleum system that has rightly been described. The only culmination is around MD-A, G and H having a major palaeo-channel possibly resulted in better sorting as compared to other areas of the field which favoured the hydro-carbon entrapment. In a fluvial braided depositional realm, a map depicting the geographic distribution of genetic units resulting from complex milieu of sedimentation is rather difficult. To quote Andrew Miall (1996) is befitting in this context. He is not only the doyen of fluvial sedimentalogy but also versatile in other fields of earth sciences. He concedes in his widely acclaimed book on Fluvial Deposits that the ancient fluvial deposits are very difficult to map. Reconstruction of closely spaced outcrops and/or