

**Title: A Note on the Occurrence of Hydrothermal Anhydrite (CaSO<sub>4</sub>) in Kanchankayi area, Bhima Basin, Yadgir District, Karnataka.**

**Key words:** Anhydrite, Hydrothermal, Kanchankayi, Bhima basin.

**Authors**

**Sikta Patnaik (Corresponding author):** Atomic Minerals Directorate for Exploration and Research, 7, West Block, RK Puram, New Delhi-110066.

Email id: [siktapatnaik.amd@gov.in](mailto:siktapatnaik.amd@gov.in),  
Mobile- 9008332117

D Bhattacharya: Atomic Minerals Directorate for Exploration and Research, Nagarbhavi, Bangalore-560072

Email id: [dbhattacharya.amd@gov.in](mailto:dbhattacharya.amd@gov.in)

K Chakrabarti: Atomic Minerals Directorate for Exploration and Research, Khasmahal, Jamshedpur, Jharkhand-831002

Email id: [kchakrabarti.amd@gov.in](mailto:kchakrabarti.amd@gov.in)

B Saravanan: Atomic Minerals Directorate for Exploration and Research, Nagarbhavi, Bangalore-560072

Email id: [bsaravanan.amd@gov.in](mailto:bsaravanan.amd@gov.in)

A K Bhatt: Atomic Minerals Directorate for Exploration and Research, Begumpet, Hyderabad, Telangana 500016

Email id: [akbhatt.amd@gov.in](mailto:akbhatt.amd@gov.in)

M B Verma: Atomic Minerals Directorate for Exploration and Research, Begumpet, Hyderabad, Telangana 500016

Email id: [mbverma.amd@gov.in](mailto:mbverma.amd@gov.in)

## A Note on the Occurrence of Hydrothermal Anhydrite (CaSO<sub>4</sub>) in Kanchankayi area, Bhima Basin, Yadgir District, , Karnataka.

**Abstract:** Presence of hydrothermal anhydrite (CaSO<sub>4</sub>) is identified from the brecciated limestone of Shahabad Formation of the Proterozoic Bhima basin, Northern Karnataka. This is specifically observed in the Kanchankayi area of Gogi-Kurlegere-Gundanhalli fault, Bhima basin. Microscopically the anhydrite is characterised by high order interference colour and straight extinction. X-ray diffraction studies further confirmed the presence of anhydrite with characteristic set of d-spacing of 4.6397Å (Intensity-60.71), 3.4584 Å (56.76) and 2.7730 Å (23.22). Subherdal to anhedral grains of anhydrite occur within the veins of sparry calcite cutting across the primary micritic calcite in brecciated limestone. It is associated with calcite, barite pyrite and carbonaceous matter. Anhydrite is present in different habits viz. tabular/euhedral, stumpy and acicular. Occurrence of anhydrite grains is localised and is restricted to the epigenetic secondary calcite. This suggests it is of hydrothermal origin.

**Key words:** Anhydrite, Hydrothermal, Kanchankayi, Bhima basin.

### Introduction:

Anhydrite is a characteristic mineral often reported from the evaporite rocks of different geological age. Occurrence of hydrothermal anhydrite is widely reported from seafloor hydrothermal deposits, black smoker chimneys (Goldfarb *et al.*, 1983; Haymon, 1983), large massive sulfide deposits (Humphris and Tivey, 2000, Humphris and Bach, 2005) and porphyry-type Cu deposits (Rye, 2005). In India, anhydrite is reported from the late Neoproterozoic and early Cambrian Bilara and Hanseran Evaporite Groups of Nagaur-Ganganagar Basin (Mazumder and Strauss, 2006). In hydrothermal system, anhydrite demonstrates a unique quality of retrograde solubility, i.e. decrease in solubility with increasing temperature. Therefore, the occurrence and composition of anhydrite is used to trace the mixing of hydrothermal fluids with sea water during high-temperature venting (Mills, *et al.*, 1998). As the Kanchankayi area of Gogi-Kurlegere-Gundanhalli fault has significant uranium mineralization, a number of workers have carried out studies on uranium mineralization and exploration. In the present paper, the objective is to report the presence of hydrothermal anhydrite in the area for the first time. The present study deals with the petrography and X-ray diffraction characterization of anhydrite reported from the study area.

### Geological setting:

Bhima basin is situated in the northwestern margin of eastern Dharwar craton. It is exposed in the parts of Yadgir and Gulbarga districts of Karnataka as well as in parts of Rangareddy district of Telangana. It comprises alternate succession of clastic and carbonate sediments (Janardhana Rao *et al.*, 1975; Kale *et al.*, 1990). The basin comprises mainly of limestone and shale with thin and discontinuous beds of arenite-conglomerate derived from the basement complex. Closepet Granite and its equivalent intrusive younger granite (2.2-2.5Ma) with subordinate peninsular gneiss and greenstone belt components forms the basement complex (Senthil Kumar and Srinivasan, 2002). In the lower most Rabanpalli Formation of Bhima basin, quartz arenites, arkoses, siltstones and shale are the dominant members (Nagarajan *et al.*, 2007a, b). Limestone is the dominant lithology of the Bhima Basin and is classified under Shahabad and Katamadevarahalli Formations. The Shahabad Formation is exposed in the central and eastern parts of the Bhima Basin (lat. 16°15' to 17°35'N long. 76°15' to 77°30'E) (Nagarajan *et al.*, 2011). Shahabad limestone is micritic in nature and has stylolites filled with

secondary minerals (Malur and Nagendra, 1994; Nagendra and Nagarajan, 2003, Nagarajan *et al.*, 2008). Bhima basin is dissected by a number of faults. At the middle of the basin, Gogi Kurlegere fault, an E-W trending 40 km long boundary fault extends from Gundahalli in the east to the Kurlegere in the west which has affected both the basement and the sediments. The fault zone near Gogi, hosts an important uranium deposit, which is structurally controlled hydrothermal vein type deposit in the vicinity of basement sediment unconformity (Pandit *et al.*, 2002, Dhana Raju *et al.*, 2002).

The study area (Kanchankayi) also falls in the fault zone and is situated about 2.5 km north-east of Gogi (Fig.1) The fault zone is highly disturbed, wherein the lithounits underwent the processes of brittle and ductile deformation along with alteration. In Kanchankayi area, uranium mineralization is hosted in brecciated limestone and also in sheared basement granite closer to the sediment basement contact within the tectonised zone (Patnaik, *et al.*, 2016, Roy *et al.*, 2016). The major two lithounits found along the fault zone in the study area are granite and limestone, where both the lithounits have undergone deformation. Basement granite shows evidences of brittle to ductile deformation. The mild to intense alterations like sericitisation, chloritization, epidotisation and hematitisation have been observed. Pichblende, coffinite are major radioactive phases present in granite besides U-Ti complex and uranium adsorbed on clay.

#### **Materials and Methods:**

The core samples were collected from 268 m to 344 m of the drilled section from Kanchankayi area (Latitude- N 16°44'37.20" & Longitude E 76°46'31.20".) for petromineralogical studies. Drilled core encountered limestone, shale and granite. Lithologs of different boreholes has been shown in Fig. 2 displaying the depth of anhydrite in each borehole. Samples were collected from various depths for regular petrological studies. In the Fig. 2, the arrow shows the depth of anhydrite in each bore hole. The petromineralogical studies were carried out using petrological microscope (Nikon Eclipse E600 pol) under both transmitted and reflected light at the magnification of 2x, 5x, 10x and 20x. X-ray diffraction was carried out for the sample in Siemens D-500 Diffractometer in XRD Laboratory of AMD, Hyderabad. The anhydrite bearing limestone sample was powdered and was subjected to sequential heavy media liquid separation using bromoform (specific gravity, SG, 2.88) and methylene iodide (MI; SG 3.31). Bromoform lights and Methylene iodide lights were taken up for detailed investigation. X-ray diffraction (XRD) study was carried out using Siemens D-500 Diffractometer in at the XRD Laboratory of AMD, Hyderabad. Monochromatic CuK $\alpha$  radiation (1.5418 Å), using curved graphite monochromator, was used for diffraction. Mineral identification was done from the powder diffraction data thus obtained by comparing the same with the relevant International Centre for Diffraction Data (ICDD) cards. Fractions of methylene iodide lights contained anhydrite.

#### **Petrography :**

Petrographic studies of core samples reveal that the rock is mainly composed of micritic calcite with clasts of quartz, feldspar, chert, sulphides, clay including illite and smectite, limonite, chlorite and glauconite as impurities. The size of micritic calcite is less than 4 microns and it is marine carbonate, which is known as primary calcite. Primary micritic calcite is the major constituents (60-70% in vol. by visual estimation), which is cut across by veins of secondary hydrothermal sparry calcite and pyrite. There are brecciated fragments of primary micritic

calcite sealed by secondary sparry calcite. Barite, anhydrite, pyrite and carbonaceous matter are present in association with sparry calcite in veins. Radioactive minerals present in the rock samples is pitchblende. Adsorbed uranium is seen in association with carbonaceous matter. Pitchblende is replacing calcite and anhydrite. At places, pitchblende is observed in association with pyrite.

**Anhydrite: Mode of occurrence**

Anhydrite is present in small volume proportion in association with sparry calcite. Anhydrite occurs in three habits like, tabular/euhedral grains (Fig. 3), prismatic grains (Fig. 4), and acicular (Fig. 5). It is also intergrown with calcite. Anhydrite has higher relief than calcite. It has high order interference colour and straight extinction. Most of the places, anhydrite is associated with secondary hydrothermal calcite. It is also present in association with barite, pyrite and carbonaceous matter. At places, anhydrite is lined by pyrite. Tabular anhydrite is noted in association with secondary calcite (Fig. 3). At places, the anhydrite is replaced by secondary calcite (Fig. 6). The anhydrite is also noted in association with pyrite (Fig. 6). In a few samples, calcite, pyrite, barite and anhydrite are noticed to be associated with pitchblende (Fig. 7 & 8). Thus, barite and anhydrite are present in mineralized as well as non mineralised samples.

**X-Ray diffraction studies:**

Diffractiongram of analysed anhydrite is shown in Fig. 9. Total 12 peaks are in range out of which 3 are matched, shown in the diffractiongram. The values of d-spacing with corresponding intensity are given in table no.1. The observed d-spacings of the investigated anhydrite are in close match with those published for anhydrite standard in ICDD PDF no. 00-003-0162.

<b>'d' spacing values and corresponding intensity for the identified peaks of anhydrite</b>	
<b>d spacing values (Å)</b>	<b>Intensity</b>
4.6397	60.71
3.4584	56.76
2.7730	23.22

Table-1: 'd' spacing with corresponding intensity

**Discussions:**

A number of mechanisms are put forward by several workers to explain the precipitation of anhydrite such as cooling of hydrothermal solution, boiling of hydrothermal solution, heating of seawater without interaction with country rocks (Kajiwara,1971, Farrell *et al.*, 1978, Farrell and Holland, 1983), heating of seawater accompanied by interaction with country rocks and mixing of ascending hydrothermal solution with seawater either above the sea water sediments interface (Sato, 1973) or below the sea water sediments interface (Shikazono,2003). When hot hydrothermal fluid and cold seawater mix with each other, transfer of heat and matter take place between the two fluids until they attain chemical and thermal equilibrium. Relative rates of heat and mass transfer between the two fluids, and nucleation of minerals may control the types of mineralization.

Precipitation of anhydrite by cooling of solution needs hypersaline solution (Muramatsu *et al.*, 2000). In the present study area, fluorite and carbonaceous matter are present in association with secondary calcite. The fluid inclusion studies on calcite and fluorite from the study area (Patnaik *et al.*, R & D report, AMD, 2014) indicates the salinity of the fluid was medium (8 wt% to 10 wt% equivalent NaCl), which rules out the precipitation of anhydrite due to cooling of hydrothermal solution. The boiling fluids are evidenced by low salinity, vapour rich inclusions i.e. 50-60% of vapour (Shepherd *et al.*, 1985), whereas the study area the liquid phase is 60-85%. Thus, the precipitation of anhydrite due to boiling of hydrothermal solution is also dismissed. The most feasible mechanism is mixing of hydrothermal solution with sea water. The schematic diagram of probable mechanism of anhydrite precipitation is shown in Fig.10 (Modified after Kuhn, 2003). The textural relation between pyrite and sulphate minerals i.e. anhydrite and barite also indicates that anhydrite or barite precipitation is followed by hydrothermal pyrite. The hydrothermal solution moved through limestone host rock and became rich in  $\text{Ca}^{+2}$ . The presence of sulphide minerals suggests that the solution was rich in iron and  $\text{HS}^-$ . Thus, when an interaction between calcium rich hydrothermal solution and sulphate rich seawater took place, anhydrite got precipitated. This was followed by appearance of an environment conducive for sulphide precipitation. Thus at most of the places anhydrite and barite are bordered by pyrite.

Most of the occurrence of massive anhydrite has been found in high temperature hydrothermal environment (Teagle *et al.*, 1998). However, precipitation of anhydrite in epithermal condition cannot be ruled out. Anhydrite ( $\text{CaSO}_4$ ) is stable at temperatures above about 150°C (Blount and Dickson, 1969, McDuff and Edmond, 1982, Tivey and Delaney, 1986, Hannington *et al.*, 1995). Precipitation of anhydrite can take place between 200°C and 350°C as shown in Fig.11 (Blount and Dickson, 1969, Hannington *et al.*, 1995). Kanchankayi area is a structurally deformed zone. As a result of faulting, fractures were developed, which acted as channels for movement of hydrothermal solutions. The mineral assemblage formed as a result of hydrothermal processes indicates the epithermal nature of the mineralisation. From the study area, fluid inclusion studies on calcite and fluorite were carried out and homogenization temperature of the inclusions is estimated to be between 180°C and 230°C (Patnaik *et al.*, AMD, Unpublished Report 2014). The brecciated limestone and cataclasite indicate the “brittle deformation zone” at shallow depth. As the hydrothermal fluid was circulating in the low pressure conditions, homogenisation temperature represents the trapping temperature. Thus, the pressure correction is not required. It shows the temperature of hydrothermal solution is within the range of the precipitation temperature of anhydrite.

In the present study area, formation of rectangular as well as acicular anhydrite crystals indicate varying degree of anhydrite saturated solution. An earlier study by Shikazono and Holland (1983) to quantify Sr partitioning into anhydrite during formation revealed that the degree of supersaturation of solution with respect to anhydrite is responsible for morphology of the anhydrite crystals.

Based on the textural relationship among various gangue and ore minerals, a paragenetic sequence is established (Table 2). It comprises 2 stages i.e. pre-hydrothermal stage and hydrothermal stage. The pre-hydrothermal stage comprises precipitation of primary micritic calcite and pyrite. Pre-ore stage comprises precipitation of secondary hydrothermal calcite, barite, anhydrite and chert and chalcedony. Ore minerals like pyrite, marcasite, chalcopyrite and galena are formed in veins and euhedral form in pre ore stage. Carbonaceous matter got deposited in pre ore stage. At places, it is observed in association with fluorite. Ore

stage refers to Uranium metallogeny, which is represented by pitchblende and coffinite. However, U-Fe-Si complex has developed during latter stage of Uranium metallogeny and extended to post ore stage due to oxidative alteration of primary uranium mineralisation. Anhydrite is replaced by pitchblende at places. It indicates that the precipitation of anhydrite is prior to ore stage and is not related to uranium mineralisation. Post ore stage is noticed by veins of calcite, quartz, chalcedony.

Minerals	Pre hydrothermal stage	Hydrothermal stage		
		Pre-ore stage	Ore stage (U- metallogeny)	Post-ore stage
In limestone Calcite ( Primary) Calcite (Secondary) Barite Anhydrite Flourite	-----	--- ----- -----	---  -----	----
Pyrite Marcasite Chalcopyrite Galena	-----	---- ---- ---- ---	----	-----  ---
Pitchblende Coffinite U-Fe-Si complex Carbonaceous matter	-----	----   (Transported)	---- ---- -----	-----

Table-2: Paragenetic sequence

**Conclusion:**

In the study area, anhydrite might have precipitated due to mixing of descending sea water with ascending hydrothermal solution along the fractures in fault zone. It is present in association with calcite, sulphides and carbonaceous matters. Most of the place anhydrite and barite are bordered by pyrite. It indicates that the precipitation of anhydrite is followed by sulphide precipitation. Presence of anhydrite in different habits like rectangular and acicular anhydrite crystals indicate varying degree of anhydrite saturated solution. The appearance of anhydrite in mineralized and unmineralised zones, paragenetic sequence and textural relations

show that anhydrite precipitation is prior to uranium mineralization and it does not have any relation with uranium mineralisation.

**References:**

- Blount C W and Dickson F W (1969) The solubility of anhydrite in NaCl-H<sub>2</sub>O from 100 to 450°C and 1 to 1000 bars, *Geochimica Cosmochimica Acta* **33**, 227-245
- Dhana Raju R, Mary K K, Babu, E V S S K and Pandit S A (2002) Uranium mineralization in the Neoproterozoic Bhima Basin at Gogi and near Ukinal- Ore petrology and mineral chemistry, *Journal of Geological Society of India* **59** 299-321
- Farrell C W, Holland H D and Petersen U (1978) The isotopic composition of strontium in barites and anhydrites from Kuroko deposits, *Mining Geology*, **28**, 281-291
- Farrell C W and Holland H D (1983) Strontium isotope geochemistry of the Kuroko deposits, *Economic geology, mon.*, **5** 302-319
- Goldfarb M S, Converse D R, Holland H D and Edmond J M (1983), The genesis of hot spring deposits on the East Pacific Rise, 21°N, *Economic Geology* **5** 184-197
- Hannington M D, Jonasson I R, Herzig P M and Petersen S (1995) Physical and chemical processes of seafloor mineralization at mid-ocean ridges in Seafloor Hydrothermal Systems: Physical, Chemical, Biological, and Geological Interactions. (1995), *Geophys. Monogr. Ser., vol. 91, edited by S. E. Humphris et al.*, 115-157, AGU, Washington, D C
- Haymon R M (1983) Growth history of black smoker hydrothermal chimneys *Nature* **301** 695-698
- Humphris S E and Tivey M K (2000), A synthesis of geological and geochemical investigations of the TAG hydrothermal fluid: Insights into fluid flow and mixing processes in a hydrothermal system, Y. Dilek, E. Moores, D. Elthon, A. Nicolas (Eds.), *Ophiolites and Oceanic Crust: New Insights from Field Studies and the Ocean Drilling Program, Geological Society of America* 213–235 Special Paper 349
- Humphris S E and Bach W (2005) On the Sr isotope and REE compositions of anhydrites from the TAG seafloor hydrothermal system *Geochimica et Cosmochimica Acta* **69** 1511-1525
- Janardhana Rao L H, Srinivasa Rao C and Ramakrishnan T L (1975) Reclassification of the rocks of Bhima Basin, Gulbarga district, Mysore state. *Misc. Publ., Geol. Surv. India*, **23** (1) 177-184
- Kajiwarra Y (1971): Sulfur isotope study of the Kuroko ores from the Shakanai No. 1 deposits, Akita Prefecture, *Japan. Geochemical Journal* **4** 157-181

Kale V S, Mudholkar A V, Phansalkar V G and Peshwa V V (1990) Stratigraphy of the Bhima Group *Jour. Palacont. Soc. India* **35** 91-103

Kuhn T, Herzig P M, Hannington M D, Garbe-Schoenberg D and Stoffers P (2003) Origin of fluids and anhydrite precipitation in the sediment-hosted Grimsey hydrothermal field north of Iceland, *Chemical Geology* **202** 5-21

Malur M N and Nagendra R (1994) Lithostratigraphy of the Bhima Basin (Central Part), Karnataka, Southern India *Journal of the Paleontology Society of India* **39** 55–60

Mazumder A and Strauss H (2006) Sulfur and Strontium isotopic compositions of carbonate and evaporate rocks from the late Neoproterozoic – early Cambrian Bilara Group: constraints on intrabasinal correlation and global sulfur cycle *Precambrian Research* **149** 217 – 230

McDuff R E and Edmond J M (1982) On the fate of sulfate during hydrothermal circulation at mid-ocean ridges *Earth Planet. Sci. Lett.* **57** 117-132

Mills Rachel A, Teagle, Damon A H and Tivey Margaret K (1998) fluid mixing and anhydrite precipitation within the tag mound1 in Herzig, P.M., Humphris, S.E., Miller, D.J., and Zierenberg, R.A. (Eds.), *Proceedings of the Ocean Drilling Program, Scientific Results*, **158** 119-127

Muramatsu Y, Komatsu R, Sawaki T, Sasaki M and Yanagiya S (2000) Geochemical study of fluid inclusions in anhydrite from the Kakkonda geothermal system, northeast Japan, *Geochemical Journal* **34** 175 to 193

Nagarajan R, Armstrong-Altrin J S, Nagendra R, Madhavaraju J, Moutte J, (2007a) Petrography and geochemistry of terrigenous sedimentary rocks in the Neoproterozoic Rabanpalli Formation, Bhima Basin, southern India: Implications for paleoweathering condition, provenance, and source rock composition: *Journal of the Geological Society of India* **70** 297-312

Nagarajan R, Madhavaraju J, Nagendra R, Armstrong-Altrin, J S and Moutte J (2007b) Geochemistry of Neoproterozoic shales of Rabanpalli Formation, Bhima Basin, Northern Karnataka, Southern India: Implications for provenance and paleoredox conditions *Revista Mexicana Ciencias Geológicas* **24** 150–160

Nagarajan R, Madhavaraju J, John S Armstrong-Altrin & Nagendra R (2011) Geochemistry of Neoproterozoic limestones of the Shahabad Formation, Bhima Basin, Karnataka, southern India *Geosciences Journal* **15**, No. 1, 9 – 25

Nagarajan R, Sial A N, Armstrong-Altrin, J S, Madhavaraju J and Nagendra R (2008) Carbon and oxygen isotope geochemistry of Neoproterozoic limestones of the Shahabad Formation, Bhima Basin, Karnataka, Southern India. *Revistas Mexicana de Ciencias Geológicas* **25** 225–235



Nagendra R and Nagarajan R (2003) Geochemical studies of Shahabad Limestone (Younger Proterozoic), Bhima Basin, Karnataka *Indian Mineralogist* **36** 13–23

Pandit S A, Natarajan V and Dhana Raju R (2002) Exploration for Uranium in the Bhima basin in parts of Karnataka, India, *EARFAM* **14** 59-78

Patnaik S, Chakrabarti K, Pradhan A K and Bhattacharya D (2016) Petrographic characteristics of carbonaceous matter in brecciated limestone at kanchankayi area, yadgir district, karnataka: genetic implications for uranium mineralisation, *Journal of Applied Geochemistry* **18** 119-124.

Roy D, Bhattacharya D, Mohanty R, Patnaik S, Pradhan A K, Chakrabarti K and Zakaulla S (2016) Deformation pattern in Gogi-Kurlegere fault zone at Gogi-Kanchankayi sector of Proterozoic Bhima basin of northern Karnataka: Implication in control of uranium mineralization *Exploration and Research for Atomic Minerals* **26** 157-176.

Rye R O, (2005) A review of the stable-isotope geochemistry of sulfate minerals in selected igneous environments and related hydrothermal systems *Chemical Geology* **215** 3-56

Sato T (1973) A chloride complex model for Kuroko mineralization *Geochemical Journal* **7** 245-270

Senthil Kumar P and Srinivasan R (2002) Fertility of Late Archaean basement granite in the vicinity of U-mineralized Neoproterozoic Bhima basin, peninsular India *Current Science* **82** 571-576

Shepherd T J, Rankin A H and Alderton D H (1985) A practical guide to fluid inclusion studies, Blackie & Son limited, Glasgow

Shikazono N and Holland H D (1983) The partitioning of strontium between anhydrite and aqueous solutions from 150° to 250°C. *Econ. Geol. Monogr.* **5** 320–328

Shikazono N (2003) Developments in Geochemistry, Geochemical and Tectonic Evolution of Arc-Backarc Hydrothermal Systems, Implication for the Origin of Kuroko and Epithermal Vein-Type Mineralizations and the Global Geochemical Cycle, Volume 8, Elsevier, Amsterdam.

Teagle D A H, Alt J C, Chiba H and Halliday A N (1998) Dissecting an active hydrothermal deposit: the strontium and oxygen isotopic anatomy of the TAG hydrothermal mound-anhydrite. In: Proc. Ocean Drill. Program, Sci. Results (Eds: Herzig P M, Humphris S E, Miller D J, Zierenberg R A) **158** pp129–141, College Station, TX

Tivey M K, and Delaney J R (1986) Growth of large sulfide structures on the Endeavour segment of the Juan de Fuca Ridge, *Earth Planet. Sci. Lett.* **77** 303-317

Figures:

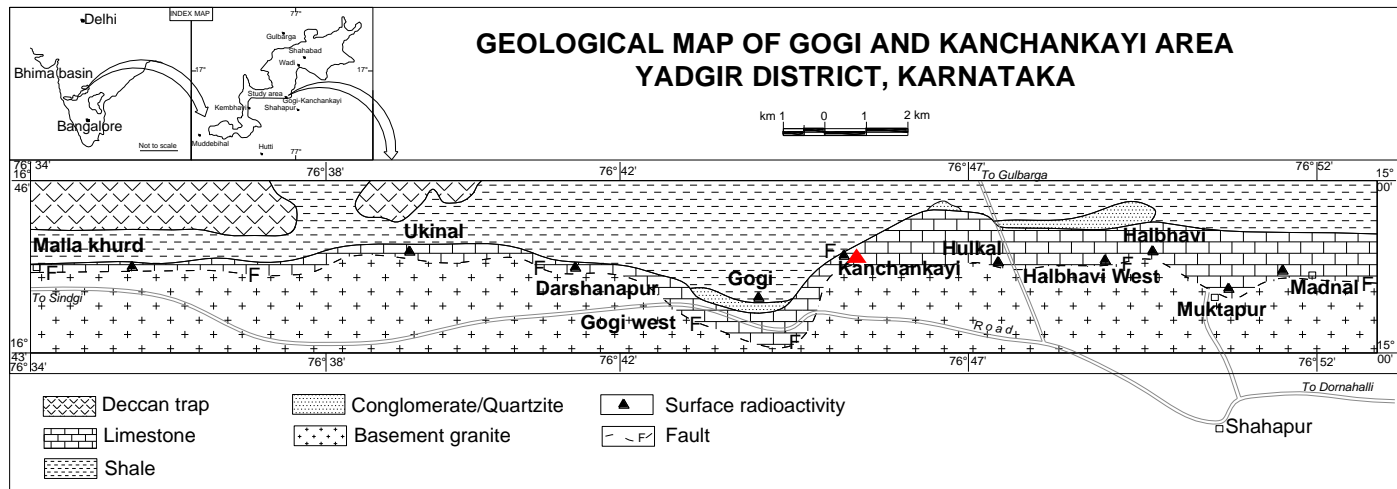


Fig.01: Geological map of Gogi-Kanchankayi area, Yadgir district, Karnataka, after Pandit et al., 2002.

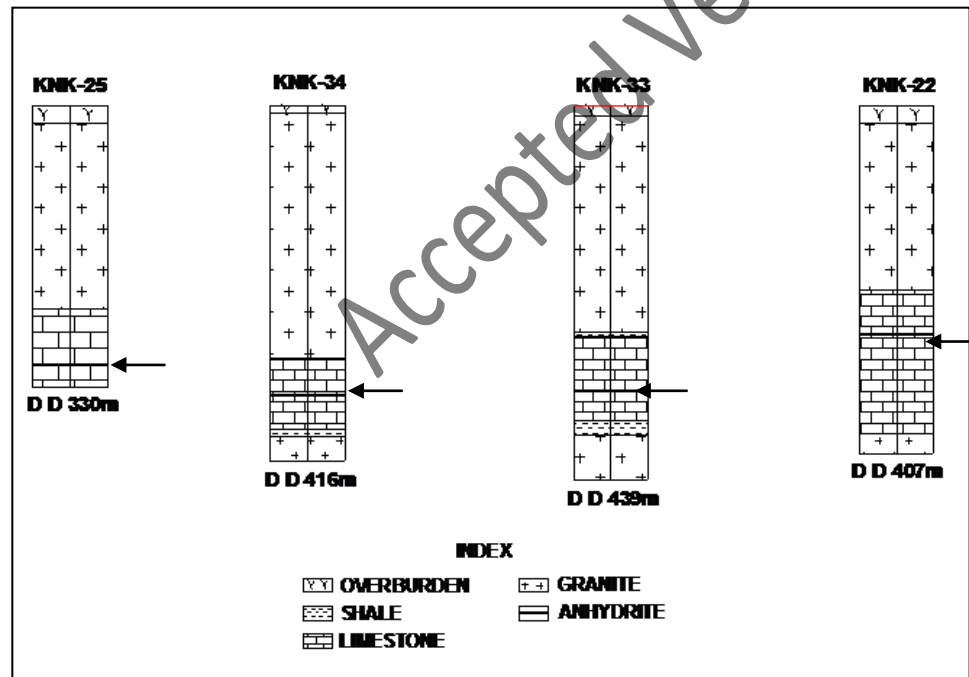


Fig.2: Lithologs of different boreholes showing depth of presence of anhydrite



Fig.03: Photomicrograph of euhedral anhydrite lath in sparry calcite (calcite II) vein. TL, XN.

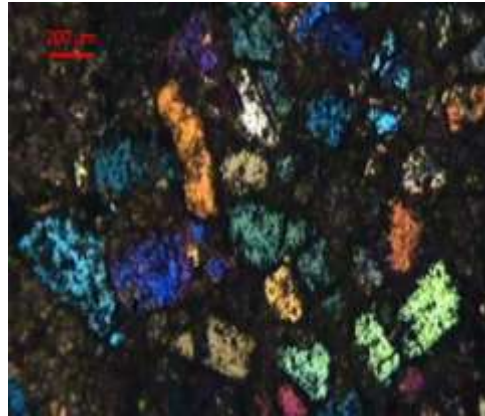


Fig.04: Photomicrograph of prismatic anhydrite grains in sparry calcite. TL, XN.

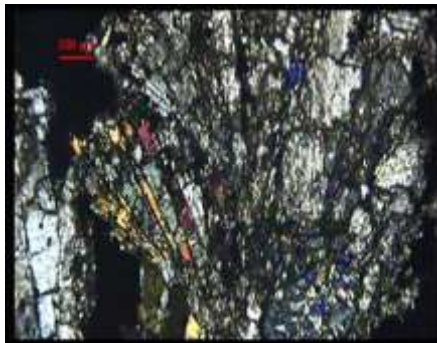


Fig.05: Photomicrograph of acicular anhydrite in sparry calcite. TL, XN.

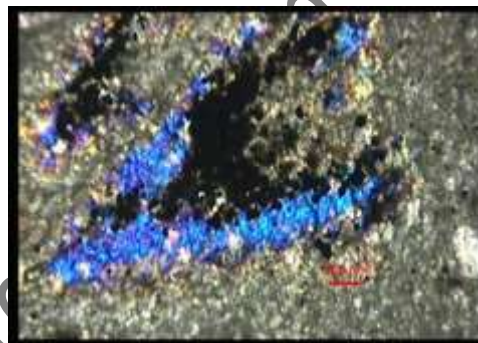


Fig.06: Photomicrograph showing anhydrite occurring in association with pyrite (Opaque) being replaced by calcite in limestone. TL, XN



Fig.07: Anhydrite with pitchblende (Pbl) and pyrite (Py). 5x, TL, 1N

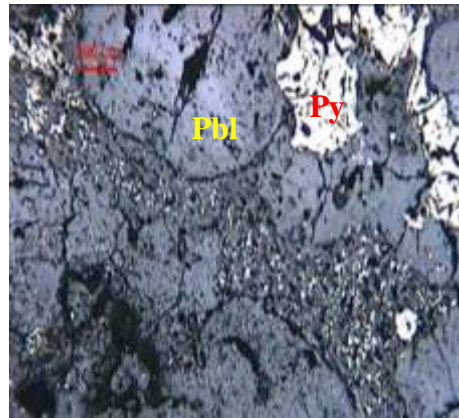


Fig.08: Anhydrite with pitchblende (Pbl) and pyrite (Py). 5x, RL, 1N

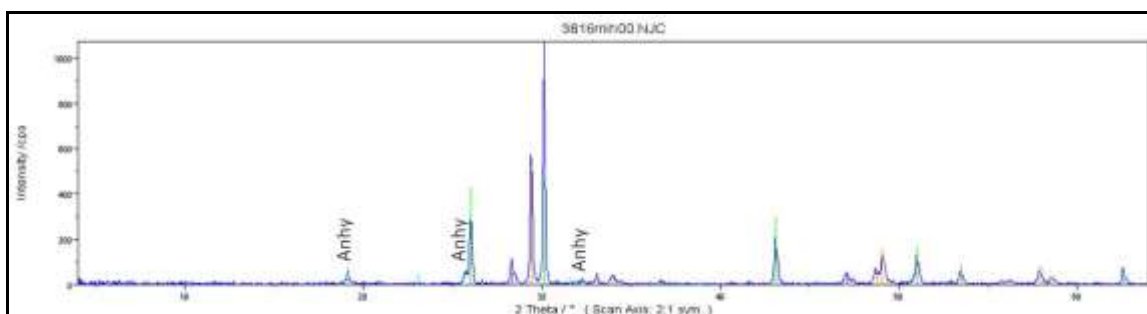


Fig.09: Diffractogram showing peaks of anhydrite identified

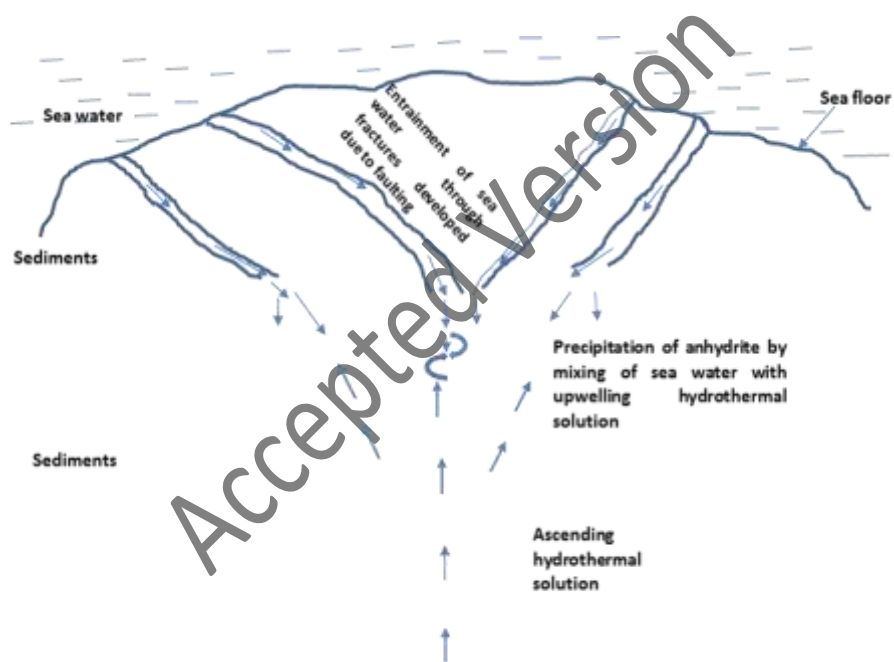


Fig.10: Schematic diagram showing probable mechanism of anhydrite precipitation. (Modified after Kuhn,2003)

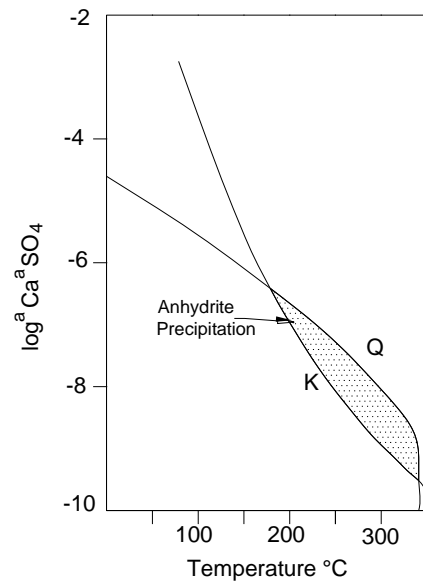


Fig11: Solubility of anhydrite for conservative mixing of 21°N-type hydrothermal fluid with seawater (K- equilibrium constant; Q- actual concentration ratio in the hydrothermal fluid) (after Blount and F.W. Dickson, 1969)

Accepted Version