CHAPTER - 10
SUMMARY AND CONCLUSIONS

In the Cuddapah Basin, an intracratonic basin in the South Indian Peninsular Craton, extensive deposits of barytes occur in the Cuddapah district (the study area) of Andhra Pradesh. The Cuddapah district has an area of 15,356 sq. km. and it lies within latitudes 13°43' and 15°14' and longitudes 77°55' and 79°29'. There are twelve taluks in the district, and barytes occurs in eight taluks only. In these 8 taluks, barytes is reported to occur in 56 localities. The deposits in the Pulivendla and the Kodur taluks are large and those in other taluks are small. The vein barytes occurs at 55 localities, whereas the grey and bedded barytes occurs at only one locality called Mangampeta, a small village in the Kodur taluk. The Mangampeta bedded barytes deposit is by far the thickest and the largest known single deposit in the world. It has 74 million tons of total reserves. The vein barytes deposits of more economic significance occur in the Pulivendla taluk. The major barytes occurrences of India are almost wholly confined to the Cuddapah district. The geological map of the Cuddapah district, in the scale of 1:250,000, has been prepared and all the 56 localities of barytes in the district are shown in the map.
In the Cuddapah district, barytes occurs in vein and bedded forms within the Vempalle and Pullampet formations respectively of the Cuddapah Super Group of rocks. The former is snow-white or white or off-coloured and the latter is grey or off-coloured.

Due to the paucity of more detailed studies on the barytes deposits in the Cuddapah Basin, there are several gaps in our understanding knowledge of the mode of mineralisation, mineralogy and genesis of the barytes deposits, especially those of Cuddapah district where they are concentrated. Therefore, a detailed study of the barytes deposits (both vein and bedded barytes deposits) of Cuddapah district has been undertaken to understand their geology, genesis and utilisation.

In the present study, three mineralised areas containing barytes and active mines have been thoroughly investigated. The areas are: (i) Pulivendla-Velidandla area (ii) Vempalle-Velpula area and (iii) Mangampeta area. Vein barytes occurs in the first two areas and bedded barytes occurs in the third area.

The geographical and meteorological features of the study area (Cuddapah district) are described. A brief review of the previous literature on Cuddapah Basin in general and on barytes deposits in particular is given. The geology of the Cuddapah Basin and also the geology of the Cuddapah district are
described in detail. Industrial uses and specifications of barytes for several industries are described. The scope and limitations in the work are outlined. The present study includes detailed mapping of the three mineralised areas containing barytes, collection of specimens for laboratory studies, collection of big lumps of barytes for mineral processing studies, study of the stratigraphy and controls of mineralisation of the ore deposits, petrographic studies of rock sections, optical studies of the thin sections of different types of barytes, mineralogic studies of ore minerals, D.T.A studies of some rocks, I.R. Spectroscopic and X-Ray Diffraction studies of barytes, Sulphur Isotope studies of barytes and pyrite, specific gravity studies of barytes, chemical and trace element analysis of the rocks and minerals using the available modern analytical techniques with U.S.G.S standards, determination of carbon in rocks and minerals, beneficiation studies of barytes by tabling and flotation, studies of the aspects and problems of mining and production of barytes, and utilisation and economic evaluation studies of barytes.

The genesis of various host rocks and associated rocks, and barytes, and their mutual relationship are studied and interpreted. The possible nature of the source material is discussed.
The Pulivendla-Velidandla area is about 242 sq. km. in extent in Pulivendla taluk and lies within the area bounded by latitudes 14°22'26" and 14°36'52", and longitudes 78°0'34" and 78°14'20". This area has been geologically mapped on a scale of 1:63,360. The Vempalle-Velpula area is about 174 sq. km. in extent in Pulivendla taluk and is bounded by latitudes 14°19'09" and 14°23' and longitudes 78°16'08" and 78°30'. This area has been geologically mapped on a scale of 1:31,680. The Mangampeta area is about 10 sq. km. in extent in the Kodur taluk and is bounded by latitudes 14°01'20" and 14°01'54" and longitudes 79°18'18" and 79°20'. This area has been geologically mapped on a scale of 1:15,840. By mapping these three different areas, the various rock types present in the areas and their field relations and structures were brought out.

The rocks of the vein barytes areas (Pulivendla-Velidandla area and Vempalle-Velpula area) are Vempalle Formation, traps (dolerites, basalts and picrites), Pulivendla Quartzite and Tadpatari Formation, which are conformable. The present investigation revealed that the said regional stratigraphy is not different from the local lithological succession. The formations have undergone considerable faulting, shearing and folding locally on a small scale. In the Pulivendla-Velidandla area three block faults, affecting the entire sequence of rocks, and in the Vempalle-Velpula area several E-W trending
faults, which are locii of barytes mineralisation, are recognised. Besides faults, shear zones are also favourable localities of mineralisation.

The Vempalle Formation is predominantly dolomite with occasional dolomitic limestone, and is intercalated with mudstones/shales, thin bands of chert and intraformational breccia. Occasionally, stromatolites or algal structures are noticed in Vempalle Formation. The traps (mostly sills) in the Vempalle Formation are of doleritic and basaltic composition. The basaltic trap sills are vesicular and amygdoloidal. Near Pulivendla, picrites are found forming multiple sills. The basalt traps and dolerite sills are often dislocated by faults, and faults are favourable localities of good barytes mineralisation in Vempalle-Velpula area. Pulivendla Quartzite, comprising a basal conglomerate, occurs as several detached outcrops. Tadpatri Formation, which is mostly a shale with ashfall tuffs, occupies low-lying plain areas. It contains thin intercalations of dolomite, dolomitic limestones and chert.

The vein barytes occurs as veins, stringers and fissure fillings mostly in the Vempalle Formation and traps and to a lesser extent in Pulivendla Quartzite and Tadpatri Formation. E-W trending faults and shear planes present in Vempalle Formation and traps are better mineralised in Vempalle-Velpula
area. Quartz veins, quartz lined vugs, chert, pyrite, chalcopyrite, and calcite are invariably found in association with vein barytes, indicating some genetic relationship with barytes. Barytes veins show caught up patches of country rock, sharp contact with the country rocks, pinch and swell shapes and high angle dips - features having some genetic significance.

The petrographic and petrochemical investigations and D.T.A studies revealed that the Vempalle Formation is not a pure limestone but consists of dolomite and calcite. Based on its chemical composition it is found that the Vempalle Formation consists of calcitic dolomites, dolomites and dolomitic limestones. The absence of rare earth elements La, Ce and Y indicates that the carbonate rocks of Vempalle Formation are dolomitic sediments but not carbonatites. The occurrence of 'ONKOLITE' (stromatolite), the nature and petrography of oolites indicate that shallow water conditions were prevailing at the time of their formation.

The petrographic and petrochemical studies of dolerites and basalts of the traps indicate that they are tholeiitic in nature.

The presence of orthopyroxene and quartz in the modal composition of both dolerites and basalts of the traps indicate
that they have an affinity for tholeiites. The $\text{Al}_2\text{O}_3/\text{SiO}_2$-$\text{MgO}$ diagram and the Silica-Alkalie diagram also prove that these basic igneous rocks are tholeiitic in nature. The basalts show very little differentiation. The high concentration of Cr in these basic rocks indicates that they are early products formed under high temperatures. The high optic axial angle ($2V$) ranging from $86^0$ to $89^0$ and the high MgO content in the chemical analysis of the olivine in picrites indicate that the olivine is rich in forsterite molecule. The high contents of Cr and Ni in picrite are indicative of its early formation from the magma at high temperatures.

The vein barytes is considered to be of three varieties based on their external appearance. They are: (i) Snow-white barytes (ii) White barytes and (iii) Off-colour barytes. The optical studies show that the optic axial angle ($2V$) of these three varieties of barytes is higher than the value quoted in literature ($+37^0$). This is perhaps related to the chemical composition. It is further noted that there is some direct relationship between $2V$ and Sr content of vein barytes. The optical, I.R. Spectroscopic and X-Ray studies have proved that there is invariable association of little quartz and calcite with barytes, and Sr is present in all the three varieties of barytes in some proportion or other. The X-ray studies and the chemical studies have further proved that there is some inverse relationship between the SrO content and the cell dimensions of
vein barytes. *Pyrite* and *chalcopyrite* are found as dissemina-
tions in vein barytes.

Based on the evidences like mode of occurrence and
controls of mineralisation, x-ray studies, chemical studies, it
is suggested that both barytes and quartz belong to the residual
solutions from the ascending magma, and barytes mineralisation
might have taken place by a process of hydrothermal differentia-
tion. The major structural features like E-W faults and shear
zones, formed during the tectonism of the Cuddapah Basin, might
have aided the hydrothermal solutions coming from greater depths.
The age of barytes mineralisation is considered to be post-igneous
intrusive and post-Chitravati.

The rocks of the bedded barytes area (Mangampeta area) are
dolomites, crystal tuffs and tuffs/black tuffs, which are strati-
fied. The grey bedded barytes and welded tuffs are an interca-
lation in the tuffs/black tuffs. Veins of white crystalline
barytes and milky quartz are found in all rocks and bedded
barytes. Pyrite of subsequent origin is omnipresent.

The bedded barytes occurs as two separate ore bodies viz.,
the northern lens and the southern lens. The northern lens
comprises 95% of the deposit. Lower granular barytes (90%),
middle spherules of barytes (rosette) in tuff matrix (≤ 5%) and
upper lapilli of barytes (≤ 5%) comprise the grey bedded barytes deposit.

The present investigation revealed that the said regional stratigraphy is different from the local lithological succession. Major part of the ore body appears to confine to the synclinal troughs of the gently folded formations, and a few faults are traced in the mineralised area.

The petrographic and petrochemical investigations revealed some variations from the known or already reported rock types from this area. Dolomite is a massive, compact, and fine-grained rock. It contains high calcium and so it may be called calcitic dolomite. Dolomites have a composition equivalent to deep sea carbonate sediment. Fine-grained nature, presence of devitrified material (mainly rosette barytes), glass shards, dust inclusions, glass, angular fragments and flow features indicate that the tuffs/black tuffs, crystal tuffs and welded tuffs are volcanogenetic extrusive products. The tuffs/black tuffs are of rhyolitic composition, and the crystal tuffs are highly silicic (94% SiO₂). Welded tuffs range from tuffs to crystal tuffs. They are hard and compact with high temperature minerals indicating higher temperature of formation. The crystal tuffs are having relatively bigger grain size with less glassy matter.

c/fm-a/alk diagrams, T-C diagrams, and Q-A-P diagrams show that all the rocks—tuffs, crystal tuffs and welded tuffs—are of eruptive origin. The Q-A-P and A-F-M diagrams indicate
that the rocks are of rhyolitic composition with alkali (potash) enrichment trend. The elemental concentrations of Cu, Zn, Co, Rb, Li and Cs indicate that the tuffs, crystal tuffs and welded tuffs are originated from a crystallization trend.

Devitrification is represented by the growth of radiating barytes laths from a common centre (rosette or spherule). Tuffs/black tuffs show the presence of some sedimentary material mixed in them.

Barytes and pyrites are the two minerals that are studied in detail. The grey granular barytes is an aggregate of minute crystals which are fine-grained and homogeneous. Rosette barytes is an aggregate of radial platy barytes (spherules) in a fine-grained tuff matrix. The white crystalline vein barytes in the bedded barytes and the replacement barytes are of some interest as they throw some light on the origin.

The major, minor and trace element concentrations of all barytes samples analysed are discussed. The presence of Cs may indicate a higher temperature of formation. The granular barytes, rosette barytes and vein barytes showed different chemical characteristics. The optical, chemical, I.R. Spectroscopic and X-Ray Diffraction studies have indicated the presence of Sr in barytes in low amounts. The I.R. Spectroscopic and X-Ray Diffraction studies of both granular and rosette barytes have proved the presence of quartz and calcite and rarely celestine as invariable
impurities in them. The x-ray data (values) and cell dimensions of all barytes types are similar to the A.S.T.M standard values of barytes except some minor variations in some samples.

Pyrite segregations are found, sometimes enclosing the grains of the host rock. Mineragraphic, x-ray and trace element studies reveal that the pyrite is of subsequent origin, and the high Ni and Cr contents in pyrite increased the values of Ni and Cr in all the rocks.

The field and laboratory studies of the rocks and minerals of the Mangampeta area indicate that the dolomites are of deep sea sedimentary origin, while the crystal tuffs, tuffs/black tuffs and welded tuffs are volcanic products. Tuffs/black tuffs (ash beds) of rhyolitic composition are formed due to extrusive volcanic activity in the deep aqueous basin. Tuffs/black tuffs are mixed with shaly matter due to simultaneous sedimentation of low magnitude. Welded tuffs are formed by the flowage of viscous ash beds into the basin during the formation of granular barytes. Siliceous residuum of the magma formed into silicic ash which later became crystal tuff. The still remaining silicic material in the source formed quartz veins in the earlier sequence of formations.

The granular barytes is formed from hydrothermal solutions while the rosette barytes is an extrusive volcanic product co-genetic with the volcanic activity that gave rise to the associated rocks. Ba$^{2+}$ as BaSO$_4$ in hydrothermal solutions coming
into the deep reducing aqueous basin to form (precipitate) granular barytes beds is suggested. Rosette barytes is the product of devitrification of barytes glass tuff which is an earlier product of extrusive volcanic activity. The presence of carbon (organic) reflects the anaerobic conditions of depositional basin due to which all the rocks and the bedded barytes are grey or black in colour. Subsequent hydrothermal activity is responsible for the barytes and quartz veins in the bedded barytes deposit and the surrounding rocks. Bacterial reduction (biogenic process) of sulphate to sulphide may be the reason for the mineralisation of pyrite and little marcasite.

In the utilisation aspect of the studies, the uses of barytes and the specification of barytes for several industries are elaborately described. The history and development of mining of barytes, the prospecting and exploration methods, the ore reserves and mining leases, grading, and certain problems encountered in mining such as, flooding of mines, subsidence and landslips, disposal of overburden, and the possible solutions for them are discussed. The cost of production, the mineral taxation rules, the production of barytes in Cuddapah district relative to Andhra Pradesh and India are described. The domestic consumption of barytes within Cuddapah district by pulverizing mills and Barium chemical units, the domestic trade and marketing of barytes within India, export policies for barytes and its export to various countries, and export facilities such as railway and port facilities are also highlighted. The country-wise reserves
and production of barytes in the world, the future trends of barytes mining and trade are discussed; and some suitable measures to boost up production and trade such as, large-scale mechanised mining, export of mud-grade barytes powder, a more planned exploration and economic exploitation, and beneficiation of the barytes of low- and marginal-grades are suggested.

The comminution, size analysis and liberation studies of barytes (both vein and bedded barytes) were carried out, and based on liberation studies the course of dressing of the two types of barytes was deciphered. The beneficiation of the vein barytes was made by tabling while that of the bedded barytes was made by flotation and the results are discussed.

The vein barytes offers no difficulty in beneficiation, but beneficiation on a large scale is not warranted since the reserves are small. There is no problem in beneficiating bedded barytes samples with 66% BaSO₄ and above, but the minimum grade of barytes that would respond to beneficiation to give a good concentrate is not found in the present study. It is envisaged that by suitable blending of the high-grade and off-grade varieties, after marginal grade improvement, the resulting product could meet the specifications of the mud-grade barytes. By adopting this strategy, it is possible to avoid selective mining and sell the entire barytes without resorting to relatively costly beneficiation techniques, like flotation where recovery is rather less.