CHAPTER VIII

SUMMARY AND CONCLUSION

This chapter summarises the salient features of the result of the investigations and contains a brief account of the geology, origin, occurrence and beneficiation of the graphite deposits of Panchmahals and Baroda districts of the State of Gujarat.

Geology

The north-eastern and eastern parts of Gujarat are characterized by Pre-Cambrian metasediments of Aravalli system (Champaner series). Geological succession of the area covering all the graphite occurrences is as follows:

Post-Aravalli Intrusives	Granites, pegmatites, aplites, quartz veins.
Aravalli	Gneisses, schists and bands of crystalline limestones with bands or layers of graphitic rocks. Mica schists and phyllites graphitic horizons. Quartzite with calc-silicate members
----------Unconformity----------	
Pre-Aravalli	Granites, gneisses and schists.

The detailed ground checking have indicated that the graphite occurrences are confined to low undulating grounds with considerable soil cover. The concentration of graphite in economic quantities is in the Pre-Cambrian metasediments. The graphite bearing rocks are phyllite, schist and gneiss. There are several parallel bands of graphite schist in the Pre-Cambrian schist, gneiss, crystalline limestone and quartzite intruded by granitic and pegmatitic rocks.

Occurrence

The graphite deposits of economic importance can be broadly classified into two categories based on the physical properties of natural graphite.

I. Amorphous graphite deposits -
Amorphous graphite disseminated in arenaceous-argillaceous sediments and calcareous argillaceous sediments.

II. Flaky graphite deposits -
Flaky graphite disseminated in arenaceous-argillaceous sediments.

Amorphous graphite, in gray to dark gray phyllite and schist, occurs as narrow and rather persistant bands varying in thickness from 2 to 5 cms. These graphitic bands appear as seams and are more or less parallel to the bedding or the foliations of the country rock. The content of graphitic carbon in the amorphous graphite zones varies from 2 to 18 per cent. Flaky graphite occurs in gray to dark silvery gray quartz-mica-schist. The graphite flakes are oriented parallel to the plane of foliation. Flaky graphite occurs in layers and lenses which are not similar in mineral composition. The percentage of graphitic carbon varies along and across the strike of the rock. The content of graphitic carbon in these deposits varies from 3 to 12 per cent.

Mining

Open cast mining methods are used to excavate graphite ore upto a depth of 15-20 meters in gentle to steeply dipping graphite bearing formations. Selective mining methods are employed to work out the deposits. Blasting becomes necessary when the overburden consists of hard and massive rocks. The run-of-mine ore contains 2 to 18 per cent fixed carbon.

Origin

Summarizing the origin of graphite, it appears that, graphite is probably formed in nature in several different ways. Graphite in metasedimentary rocks have an origin wholly different from graphite of veins and pegmatites.

All the graphite occurrences in Gujarat are within the Pre-Cambrian metasediments which suggest the formation of graphite as a result of metamorphism of carbonaceous sediments. The field evidences given below are in support of organic origin and the presence of carbonaceous matter in the original sediment.

1. The bands or layers or seams of graphite are more or less parallel to the bedding of crystalline limestone (Ankli, Jhab-Redhana), parallel to the

bedding of quartzite (Nadatod, Narukot), and quartz-mica schist (Sewania, Virpur).

2. The strike of the graphite bands is parallel to the strike of the bedding foliations of the graphite schist.

3. The sharpness of the contacts of veins of quartz pegmatite and granite with graphite bearing rocks and the absence of graphite in the fractures (joints) and the foliations more or less perpendicular to the intrusive contact.

4. The grains, flakes and foliations of graphitic rocks are uniformly distributed for considerable distances away from the contact, except at the extreme contact and there is absence of larger concentration near the contact zone.

5. Complete absence of vein type, crystalline graphite bearing horizons cutting across the graphite schist.

6. With the distance increasing away from the contact zone there is decrease in size of the graphite flakes.

It is observed that graphite deposits contain 5 to 22 per cent of fixed carbon. The rocks are grayish to dark silvery gray, well-foliated schist. Under the microscope, the thin section study revealed that the original material is quartzose with clay impurities and consists of invariable amounts of carbonaceous matter. Quartzose grains along with clay impurities recrystallized due to low grade temperature, pressure effects have given rise to elongate grains of quartz along with muscovite and chlorite. Simultaneously indigenous carbonaceous matter was converted into graphitic carbon. Due to the combined effects of temperature and pressure, the grains are arranged so uniformly that the rocks show schistose structure mainly due to sub-parallel orientation of quartz grains enclosed by flakes of mica and graphite.

The intensity of metamorphism is low to moderately high and various mineral assemblages point to a chlorite grade. This Green-schist facies is succeded by a moderate to high grade Biotite-zone with the appearance of abundant biotite and sillimanite. The rocks point to metamorphic changes governed by low temperature and moderate pressure conditions and assemblages belong to Green schist facies of Turner and Verhoogen (1962).

The effects of the superimposition of contact metamorphism over regional metamorphism are seen as progressive recrystallization of fine grained schist to medium grained schist and gneiss. The contact effect on impure crystalline limestone and associated rocks has resulted into the formation of wallastonite, diopside, epidote, tremolite, serpentine and sphene.

In brief, all the graphite bearing rocks show well-foliated nature and complete schistose structure which is the most important character developed in regionally metamorphosed rock. Graphite occurs in Pre-Cambrian metasedimentary rocks viz. phyllite, schist and gneiss associated with crystalline limestone and quartzite. An understanding of the probable mode of origin of the graphite is of much value in exploration of graphite deposit. The detailed geological field observations and laboratory investigations suggest that the graphite is of organic origin derived from the metamorphism of carbonaceous matter, in two stages as follows:

I. The sediments with indigenous organic matter were affected by the progressive regional metamorphism resulting into phyllite, schist and gneiss. During moderate to high grade metamorphism the carbonaceous matter was converted into graphite and was oriented along the schistosity and/or gneissosity of the rocks.

II. Phyllites and schists formed due to low grade metamorphism were intruded by igneous bodies. The heat emanated from these intrusive bodies was responsible for the transformation of carbonaceous matter to graphite.

Beneficiation

The graphite ore from each of the four mines viz. Ankli, Sewania, Virpur and Muthai were upgraded and tested for the grade and recovery of their final concentrates.

The amorphous graphite from Ankli, Sewania and Muthai consists of fine to very fine grains or tiny flakes, disseminated in phyllite, schist and gneiss. The flaky graphite from Virpur consists of flat, plate like flakes disseminated in schist and gneiss. The average assay of the ore is 2 to 18 per cent fixed carbon. The chief impurities in graphite ore are quartz, feldspar, mica, calcite, iron sulfide and silicates of calcium, magnesium and aluminium. Most of the graphite was liberated from gangue minerals when the ore was ground to 100 mesh, but it was fully liberated at 200 mesh. It is difficult to beneficiate amorphous graphite on account of its extreme fineness. Mica, totally free from graphite could not be mechanically separated because of their flaky nature. During Rougher flotation, the flotation reagents used were Kerosene oil, Diesel oil and Pine oil (8:8:1 by vol.) in which Kerosene and Diesel oil were used as collectors and Pine oil as a frother. Emulsification of these reagents in water before addition to pulp, reduced the conditioning time as well as consumption of reagents. Their consumption during rougher flotation and cleaning operation was 0.5 kg/tonne and 0.2 kg/tonne respectively. Calgon (Sodium hexameta phosphate) was used as depressant during cleaning operations which were conducted with water containing 150 mg of calgon per litre of water (pH = 6.6). The rougher floats of all the samples were cleaned in the presence of depressant. Rougher floats of ores from Ankli and Muthai were cleaned once and those from Virpur and Sewania were cleaned thrice using water only.

Further grinding of amorphous graphite was not taken up because of the problem of entrainment and increase in ash content. The flotation characteristics of Virpur graphite were found to be the best. The final concentrate and recovery from various deposits gave the following results.

Locality	Type of Graphite	Per cent Fixed carbon by wt. (by diff.)	Per cent Recovery
Ankli	Amorphous	28	99.0
Sewania	Amorphous	29	98.7
Virpur	Flaky	87	98.7
Muthai	Amorphous	32	99.5

Industrial applications

On the basis of the physical form of graphite particles, the natural graphite is classified for industrial purposes into three types viz. amorphous, lump or chip and flaky.

In Gujarat, amorphous and flaky varieties are found. Amorphous graphite is a microcrystalline graphite having extremely fine grained texture, which can be identified only under the microscope.

Flaky variety consists of isolated, flat, plate-like particles with angular, rounded or irregular edges. It is graded according to carbon content, flake size and kind and amount of impurities.

Carbon content and particle size are important factors for industrial use of graphite. The amorphous graphite from Ankli, Sewania and Muthai can be used in foundry facings, moulds, etc. The flaky graphite from Virpur, can be commercially used in dry cells, refractories, crucibles for melting metals and lubricants.