ORIGIN AND OCCURRENCE OF GRAPHITE DEPOSITS IN THE PRECAMBRIAN FORMATIONS OF GUJARAT

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ABSTRACT

The Precambrian terrain of Gujarat occupies the north-eastern and eastern parts of the state. These rocks consist of very ancient metamorphic and igneous rocks ranging in age from 2000 million years to about 800 million years. The concentration of graphite in economic quantities is found in the Precambrian metasediments at Sewania and Ankli of Panchmahals district and Virpur, Muthai and Jaloda of Baroda district. The graphite bearing rocks are phyllite, paraschist and paragneiss. The chief constituents of these rocks are quartz, feldspar, micas and graphite with varying amounts of calcium and iron minerals. The associated rocks are quartzites, crystalline limestones and granites.

Amorphous graphite is commonly found in the form of minute particles more or less uniformly distributed in seams in low grade metamorphic rocks such as phyllites and schists. Flaky graphite occurs in schist intruded by pegmatite or granite.

The field observations in support of organic origin of graphite are as follows:

(a) The seams of graphite are parallel to the bedding planes of metamorphosed sedimentary rocks, (b) the strike of the foliation in wall rock is parallel to the strike of the graphitic schist, (c) the extreme sharpness of the pegmatitic vein and scarcity or absence of graphite in the wall rock. The foliations are more or less perpendicular to the intrusive contact. (d) the grains, flakes and foliations of graphitic rock in contact with granitic veins or pegmatites are more or less uniformly distributed for considerable distances away from the contact and absence of larger concentration of graphite in the immediate contact zone, (e) fairly even dissemination of the graphite through the graphitic phyllites and schists, (f) absence of crystalline graphite, (g) the transition from amorphous carbon to graphite in the carbonaceous phyllites near the intrusive contact, (h) presence of scattered grains of pyrite in the graphite bearing metasediments.

From the above evidences, the present authors conclude that the graphite in these rocks is of organic origin and the graphite bearing rocks are formed as a result of metamorphism of the Precambrian carbonaceous sediments containing algae, bacteria etc.

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INDUSTRIAL APPLICATIONS OF NATURAL GRAPHITE

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In ancient times, graphite was used mainly as writing material. Since then, the use of graphite has increased manyfold. Today, it is being used in many industries, viz., in the manufacture of crucibles, pencils, paints, lubricants and in foundry facing. Lurgest consumption of graphite is in metallurgical industries. Quality of graphite and cost of production are the deciding factors for the use of graphite in various industries. The properties of graphite must be assessed before use. Artificial graphite made from petroleum coke has replaced natural graphite in atomic reactors where purity is an important factor. The problems arising out of the application of graphite in various industries can be solved by closer co-operation between producers and users.

Introduction

Graphite is a crystalline form of carbon. All graphite is crystalline but fine grained graphite is commercially known as amorphous graphite.

In the 18th century, it was variously known as plumbago, molybdaene, by-ertz or black lead.[1] Karl Wilhelm Scheele (1742-1786) was the first to distinguish between graphite and molybdnenite and proved that graphite contain carbon by igniting it in a current of oxygen.[2] It was named "Graphite" by Werner in 1789, derived from the Greek word "Grapho" means "to write".

Graphite ranging from 25% to 100% graphitic carbon is consumed in various industries. About 70% of the world's total consumption of graphite is in metallurgical industries viz., crucible manufacture, foundry facings, moulds etc. Other important uses of natural graphite are in lubricants, brushes for electrical machinary, dry cell battery, electrodes and pencils etc. Minor use of graphite is in explosives, preventing boiler scales etc.

The use of graphite as an important industrial raw material is mainly due to the following physical and chemical properties :—

1. Metallic lustre,
2. High opacity,
3. Flaky form,
4. Softness,
5. Low specific Gravity,
6. High electrical conductivity,
7. Good conductor of heat,
8. Chemical inertness,
9. Low coefficient of friction.
10. Refractoriness.

Industrial Classification of Graphite :

In the industries, natural graphite is classified on the basis of the physical form of graphite particles, into three principal types as follows—

Flake,
Lump or chip,
and Amorphous.

Flake graphite is isolated, flat, plate-like particles with angular, rounded or irregular edges. It is graded according to carbon content, flake size and kinds and amounts of impurities. The average size is no more than about 0.5 cm. Thickness, toughness, density and shape can differ.

Lump or chip graphite is denser and has greater degree of toughness than other forms of graphite. They may be long, pointed or irregular sharp cornered fragments.

Amorphous graphite is a microcrystalline graphite having extremely fine grained texture, which can be identified only under microscope. Commercially, finest sizes of flake and lump graphite is designated as amorphous graphite. Amorphous graphite can vary in graphitic carbon content and particle size which are important factors.

Classification of graphite according to Glembotskii V. A., et. al. based on structure of the graphite is as follows[3] :—

Flaky—consisting of separate lamellar crystals less than 1 mm and upto 5 cm.

Close grained—consisting of flakes which are much smaller and less than 0.1 mm and are oriented in various directions.

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Microcrystalline—consisting of grains which are less than 1 micron.

Graphite from Ceylon has been classified on the bases of graphitic carbon content and particle size as follows [1]

	Graphite carbon %	Particle size
" Amorphous " lump	90–98	1½ 3/8 approx.
" Crystalline " lump and chip	85–90	3/8 – 1/8 approx.
" Amorphous " dust	55–85	36 – 60 B.S.S.
" Amorphous ' flying dust	50–90	under 60 B.S.S.

Graphite Based Industries

The application of graphite in the field of metallurgy falls into two main forms, the one where the graphite is used electrically to produce the heat for the work, and the other where the graphite acts as a refractory to hold the work while it is undergoing heat treatment. Of the many properties possessed by graphite, the most important in metallurgical applications are that they are not wetted by most molten metals and that they are able to withstand several thermal shocks, provided the material is truly dry.

1. *Crucible Manufacture.* About 70-75% of the world's output of graphite is estimated to be consumed in the manufacture of crucibles, used in melting metals, such as, steel, brass and other non-ferrous alloys.

In manufacture of graphite crucibles, graphite is main constituent used, due to its characteristic properties, such as, resistant to attack by ordinary chemical reagents, infusible in most common fluxes, high melting point and a high point of vaporization. Graphite is an extremely good conductor of heat and thus graphite crucible is able to stand sudden changes of temperature.

All the three classes of graphite i.e. flake, lump or chip and amorphous are used in the industry. It is claimed that crucibles made with flake graphite withstand greater thermal stress. During expansion and contraction, thin flakes would permit of a certain amount of slipping movement amongst themselves, being in more or less parallel arrangement, and would counteract the tendency of the wall to crack. Ceylon graphite, owing to its extreme purity and dense character is extensively used in crucible industry. On grinding, this graphite breaks up into more or less angular fragments of a wedge or rod-like shape, possessing material thickness and commonly considered to form a better bond with the clay used than do the thin, flatflake graphites, as well as to resist oxidation longer. Graphite containing impurities as mica, calcite, pyrite, quartz etc. affect the life and strength of the crucibles. For high temperature use, graphite content is 80% or more but such a high percentage will reduce the crucible strength. Varying percentage of graphite used in different crucible industries are—

Types of Crucible	*Percentage of Graphite*
Copper alloys crucible	10%
Brass making crucible	5%
Razor steel making crucible	6%
Pure steel making crucible	5.6%

Amount of graphite used in the manufacture of steel making crucibles decreases as the quality of the steel increases, because graphite readily absorbed in the metal, causing defects in the metal structure.

The other raw-materials used in crucible industry are, fire proof clay, sand, small quantities of charcoal, retort graphite, coke, quartz etc. Density of the material used is an important factor in determining the crucible strength e.g. Feldspar is added to the crucible mix for manufacturing brass-melting crucibles, which increases the density of the crucible mix within the temperature range from 1300°C to 1350°C and reduces the absorption of metal by the crucible. Clean, fine ground quartz sand is usually used in crucible mixture to reduce shrinkage of the crucible body. 'Grog' (generally burned clay) is added to reduce shrinkage and prevents fracturing and excessive corrossion of the crucible by slags or fluxes. Different types of clays of varying characters are used. In mixing clay, the proportion is much more important, because greater amount of clay lowers the ultimate density and thermal conductivity. Therefore mixture is prepared according to their specific uses.

2. *Foundry Facing.* The term 'facing' in general usage is applied to the facing material which forms a layer about an inch thick around the pattern, in short, it is the material which are used to give the skin of moulds, a smooth finish, so that casting peel freely and clearly on cooling, and prevent adhesion of the moulds.[2]

Graphite is an admirable material for foundry facing and the binding material is usually clayey and of refractory nature. Sometimes talc, soapstone, carborundum, sand or mica may be added to improve the characteristics of the mixture. It is important that amount of graphite in the facing should be carefully controlled. The binder absorbs a certain amount of moisture from the mould, and this holds the facing in place; and when the clay is calcined by the molten metal, the facing is rendered some what porous, allowing the exit of the moisture and occluded gases.[2]

Finely ground amorphous graphite or dust derived from lump graphite is generally used for foundry facings.

With regard to the grade of graphite best adapted for foundry facings, the best results are obtained by the use of high grade flake. Purity requirements vary widely within the range of 40-70 percent graphitic carbon. Sulphides and other readily fusible minerals are deleterious, but quartz, mica and other silicates are permissible.

Thus low-grade graphite dust from refining mills, is the chief source of graphite material suitable for manufacturing of facings.

3. *Brushes.* Dynamo and motor commutators were formerly made of copper brushes. Such brushes have now been almost entirely superseded by carbon or graphite brushes.

Graphite brushes are self-lubricating, have long life and of high electrical conductivity as compared with carbon brushes. The tendency of dynamo to spark at the brushes also, is greatly lessened by using brushes made of comparatively high resistance material, such as carbon or graphite, in place of low resistance material like metal. Most brushes in the graphite class are non-abrasive or slightly abrasive.

Generally the graphite used may be the natural flake variety or Ceylon plumbago. But brushes made of artificial graphite are extensively used in direct current machines. There are numerous types of brushes in the market, composed entirely of graphite except binding material, which are characterized by high carrying capacity, medium contact drop and low coefficient of friction, especially for high commutator speeds.

Depending on the capacity of the brushes for transmitting current, various types of brushes are manufactured. The brushes carrying heavier current may contain as much as 90% of copper. The other types contain pure graphite or a mixture of graphite and petroleum coke in a finely powdered state with or without powdered copper thoroughly incorporated with binder coal tar and benzol. Certain brushes have pigtail socket at their upper end, which is electroplated with copper and others are tinned by dipping the copperplated brush into molten tin.

The Morgan Crucible Company, of London, make graphite brushes, having composition, known as Morganite, which consists of Ceylon or flake graphite.[2] This graphite brushes constructed in layers, in such a way that the resistance across the brush is from seven to eight times that in the opposite direction.

Metal brushes are objectionable, because, it is difficult to keep the surface of the commutators smooth, and there is always a tendency for soft metals to become rough when rubbed together.

4. *Dry Cell Battery.* Graphite is intimately mixed with manganese-dioxide, a poor conductor of electricity, to produce the desired conductivity of the cell. Manganese-dioxide plays an important role in the electrochemical reactions of the dry-cell.

Natural or artificial graphite may be used for this purpose. Of these, either amorphous graphite or finely ground flake graphite is applied in dry-cell manufacture. Generally graphite containing 85 to 90% graphitic carbon is used. Impurities, such as, goethite, hematite, pyrite, calcite, azurite, magnesite, silica or mica has very little effect on cell-performance, only pyrite and azurite corrode the cell.

The cell performance is affected by particle size and crystallographic orientation of the graphite particles.[1] In this, the fine grinding is more important than the complete removal of impurities.

In particular, metallic elements should be absent or present only in trace quantities. Copper, nickel, cobalt, arsenic and antimony are tolerated only in minute quantities, but sulphur and iron content should not exceed the 0.5% and 2.5% respectively. Partial analysis of suitable graphite shows, ash contents ranging from 7 to 12%. Ash consists of SiO_2 and Al_2O_3, with small percentages of CaO, MgO, Na_2O and K_2O may be allowed.

Normally acceptable ratio of manganese-dioxide to graphite for battery grade graphite is of an order of approximately 4 : 1.

5. *Lubricants.* Graphite is ideally suitable as a lubricating agent, because of its softness, low coefficient of friction, chemical inertness and heat resistance, maintained under most normal conditions. Graphite is used, due to its ready adherence to metal surfaces even under lightest pressure, where conventional lubricating oils or greases cannot be applicable.

Graphite is mixed with oil, grease or water for normal lubrication, but for some special purposes, dry flakes or powered graphite may be used. Graphite containing 95 to 98% graphitic carbon is generally preferred and it must be free from abrasive impurities, such as, quartz and feldspar or if present, allow in negligible proportion, sulphides or free sulphur are objectionable, while, ash is permissible upto 5%.

6. *Paints.* To protect the surface of the metal from corrosive action of sulphurous gases, acids, alkalies etc., graphite is used as the pigment in the paint industry. There is diversity of opinion as to the most suitable kind of graphite for graphite paints and the natural amorphous, natural flake and artificial varieties are all employed by different manufacturers. The variety of

graphitic paint depend on the percentages of graphite present i.e. purer the pigment (graphitic), poorer the paint. Pure graphite having about 80 to 90%, mixed with linseed oil, forms a porous, fluffy film, and the particles of graphite coagulate in the linseed oil with a unsatisfactory covering which on application spreads into an excessively thin coating. To overcome this it is necessary to use impure graphite. Sometimes, heavy pigments such as, lead or zinc compound are added to graphite to serve its purpose very well.

In paints, mix composed of graphite is about 50-55% and 20 to 25% silica have been extensively used. Calcium carbonate or ferric oxide are also added to graphite. In graphite paints, the names as green graphite, red graphite, brown graphite, are occassionally used. In reality such types of graphite do not exist, but they are named after the colour of the pigments.

These paints are considered especially valuable for metal and other roofs in a smoke laden atmosphere, tanks, pipes, boiler fronts, smoke stacks, gassometers, steel railroad cars etc.

7. *Boiler Scale Preventor.* In recent years the use of graphite in boilers, for preventing scale has been widely used. The action of graphite is purely mechanical and is not affected by variations in temperature or changes in acidity or alkalinity of the water or by heat.[2]

Boiler scale greatly lowers the conductivity of the boiler heating surfaces. Small particles of graphite, penetrate through minute fissures, cracks and crevices existing in the scale and gradually enters between the scale and the metal, loosening the scale so that it may be readily rapped off or removed. This way any hard scale may be effectively prevented.

The graphite usually recommended for preventing boiler scale is very finely ground flake so as to ensure maximum penetratian into the scale. In some cases amorphous or artificial varieties also are used.

8. *Pencils.* About 7% of the total world's production of graphite is estimated to be consumed in the pencil industry.[2]

Pencil "lead" consists of a mixture of graphite and finely ground clay. Occassionally stibnite (grey antimony) and lamp black may be added to improve its characteristic. Clay is used as a binder, and the hardness of the finished pencil depends upon proportions of the clay and graphite used in the mix. A high grade stoneware clay is generally used as a binder. For pencil manufacture, finely ground, earthy and amorphous graphite having about 85% graphitic carbon is employed. Flake graphite is unsatisfactory, owing to its tendency to retain flaky property even if finely ground. Artificial graphite is not suitable for pencil as it is composed of particles of carborundum. Hard and gritty impurities are objectionable and to remove the grittiness or to render them tough the lead may be allowed to boil in wax or tallow.

Formerly, pencils consisted of rods of pure graphite cut from the massive material. Later, these rods were inserted between two pieces of grooved wood. e.g. red cedar, pine and fir. The clay in pencil-lead mixtures is governed by its property of hardening when heated, as well as by its plasticity.

In general, the softer grades of pencils have leads of greater diameter than the harder ones, in which larger proportion of clay is used. The greater the amount of clay used, the harder and less lustrous will be the lead. A closest supervision is needed to the quality of the raw materials and their proportions in pencil manufacture.

9. *Explosives.* Graphite controls the burning rates of smokeless powders by coating the powder grains.[1] It also prevents excessive friction of powder grains. Natural graphite is normally preferred but electrographite also gives satisfactory results. The finely ground graphite should be free from sulphides and free acids, the acidity can be removed by washing it with soda and silicates should only be present in trace quantities. In explosive manufacture, various grades of micro-crystalline graphite are used.

A British Explosive firm manufactures, black powder explosives and propellant explosives. Maximum water percentage is about 0.1 in both these types. The clay employed in black powder explosives and propellant explosives is 10% and 3% respectively. Very low proportions of sulphur is present or added in propellant explosives.

10. *Stove Polish.* An amorphous natural graphite of having about 80 to 82% graphitic carbon is usually preferred for stove polish. In the case of solid polishes, graphite incorporated in the form of paste, cream, cake, powder or liquid with clay, rosin, asphaltum or soap binder and gassolin or water for the liquid kinds. A high degree of purity is not essential in this manufacture and carbon black is added to intensify its colour.

11. *Nuclear Reactors.* In nuclear fission, neutrons are emmited with a great kinetic energy and velocity. For controlling and lowering these factors, moderators and reflectors are used. The materials, slowing down neutrons are known as moderators and those reflecting neutrons in reaction area are called reflectors.[1]

In West Germany, nuclear grade material for moderators and reflectors from natural graphite was commercially produced. High purity of the material and elimination of neutron absorber elements like Boron are the prime considerations. Oxides of iron and other metals are removed by chloridization and silica is eleminated by heating in a stream of hydrogen fluoride. Small proportions of clay may be permissible.

In recent years, artificial graphite has replaced natural graphite in nuclear reactors.

Concluding remarks :

Particle size and graphitic carbon content are the essential considerations in graphite based industries. Largest producers of graphite are Ceylon, Madagascar, and Austria. Other countries producing graphite are Korea, Germany, Mexico, South Africa, Spain, United States etc. Ceylon graphite (plumbago) is used in metallurgical industries in many countries owing to its greater refractoriness, dense character, purity etc. Most of the Korean graphite is amorphous and is used in stove polish, paints etc. Flake graphite of Germany is used in crucible manufacture. Madagascar Flake graphite is consumed mainly in crucible industries and fines are used in other graphite based industries. Mexican graphite is much in demand for pencil manufacture and is also used in the manufacture of lubricants, graphite brushes, paints, electrotyping etc. South African graphite is used in paints, lubricants, foundry facing and boiler scale prevention. United States produces all the three varieties of graphite, flake, amorphous and chips. Spain produces crucible grade graphite.[4]

In recent years, Natural graphite is replaced by artificial graphite in moderators and reflectors for atomic reactors, crucibles, moulds and dies. Natural graphite is mixed with carbonaceous binder and the mixture is then heat treated to drive off volatiles and to carbonize the binder. This material can further be converted to electrographite or artificial graphite by 'graphitizing process' which includes additional heat treatment at a higher temperature.[5] The problems arising out of the application of graphite in various industries can be solved by closer co-operation between producers and users.

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Geological investigations of the Fulpari graphite deposit, Panchmahal district (Gujarat State)

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ABSTRACT

In the paper details of Fulpari - graphite deposit, situates at 1.5, to 2 K.M. North of Sewania are given origin and nature of deposit are dealt. The graphite bearing rocks have been studied for their chemical composition, mineralogical composition, texture and structure. The appraisal of mining and benefication methods have been recorded. Further works on origin and age of graphite bearing formation are in progress.

Introduction

The Fulpari graphite mine is located on the right bank of the tributary of Panam river at a distance of 1.5 to 2 km. North of Sewania. The mine forms a part of the Fulpari village and is surrounded by a plain cultivated ground. The water table in the wells is deep below 24 metres. The mine is closed during the monsoon. The mine is accessible in fair weather only by a cart track from Sewania which is linked by a metalled road with Devgad Baria and Chota-Udaipur. The graphite ore from the mine is transported by truck along a cart truck upto Sewania and along a metalled road upto Devgad Baria where the beneficiation plant is situated. The run of mine ore containing about 15 percent of graphite is upgraded to 55-70 percent graphite. The finished product is sent to Baroda by road for marketing. After a shut down period of two to three years the mine was reopened in October 1974. The capacity of the beneficiation plant at Devgad Baria is 8 to 9 tonnes per month operating one shift only.

Previous Work

E. J. Beer (1919), was first to report the occurrence of the graphite bearing rocks near Baria, the capital of the former Baria state. B. Rama Rao (1931), gave a detailed account of the regional geology of the area and published a geological map of the Baria state. The Department of Geology and Mining, Government of Gujarat, started geological surveying and prospecting work in 1964 and the work is still in progress. B. Lakshminarayan (1969), has published an article on the nature of graphite deposits near Baria.

Scope of Investigation

The present authors have undertaken the detailed geological investigation of the Fulpari graphite deposit with a view to establish the origin of graphite and the nature of the graphite deposit in this area. The graphite bearing rocks have been studied for their mineralogical and chemical constituents. The thin section study under the microscope reveals the texture and structure of the rocks. The appraisal of mining and beneficiation methods have been recorded. The investigations on the origin of graphite and the age of the graphite bearing formation are in progress.

Geological Setting

The main rock type in the mined area is a graphite bearing calc-schist of pre-cambrian age intruded by younger granite. The regional strike of the schistose formation is east-west and the dip varies from 35-50° due north. The schistose formation appears to be metamorphosed pre-cambrian sediments and consists primarily of quartz, feldspar, hornblende, calcite and graphite. The pink coloured medium to fine grained granite is highly fractured. Two sets of joints are apparent, both having east-west strike but dip of one set is almost vertical and another set is having dip of 40-50° due north. Distinct veins of milky quartz and minute veins of calcite are oriented parallel to the foliation of the schistose formation.

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Nature of the Ore Deposit

Graphite is highly disseminated along the foliations of the schistose rock. The concentration of graphite in the schistose rock is in the form of bands which vary in thickness from 1 cm. to 7 cm. The percentage of graphite in the rock increases with depth. The schistose rock is more compact near the contact of granite.

Working of the Mine

The graphite deposit at Fulpari is worked by opencast mining method by Haswin Minerals Graphite Mfg. Co. The length of the mined area is 30 to 35 metres and the width is 12 to 15 metres. The ore excavated by picks and collected by spades in buckets is carried on the head by labourers and is dumped on the surface. The mining is selective and the run of mine ore having higher percentage of graphite approximating more than 18 percent carbon, is soft and blackish in colour and the low grade ore having about 14% carbon is greyish black and hard. The two types of ores and the waste material from the mine are dumped separately. Benches of 1.5 to 2 metres width are cut on north-eastern and south-western flanks of the mine approximately at a level of 9 metres and 6 metres respectively below the surface for the purpose of deeper mining. In this area water table lies 24 metres below the surface hence any mining below this depth faces water problem. For deeper mining it is necesary to pumpout water by diesel pump. The mine is worked in one shift only and local labourers are employed on daily wages. The granitic instruction forms the hanging wall on the eastern flank of the mine has to be blasted and removed to reach the graphite bearing schist.

Petrological study

In thin sections graphite bearing calc-schist show schistose structure and microfolding. The grains of quartz are elongated and show wavy extinction. Flakes of graphite are oriented parallel to the foliation. Calcite mostly occurs in the groundmass. Iron minerals (mostly hematite) are found in the form of bands parallel to the foliation. Veins of secondary quartz and calcite are also found along the foliation. The intrusive granite in thin section shows the presence of quartz, orthoclase, microcline, acid plagioclase and mica.

Geochemical study

One representative sample (Sm) of the entire mine and two selective samples (S1, S2) from the graphite bearing horizons in the schistose formation were collected from the mine and tested in the chemical laboratory of Directorate of Geology & Mining at Ahmedabad. The samples S1 and Sm contain 18.24 and 23.00 percent fixed carbon respectively out of which 4.91 and 1.82 percent is non-graphtic carbon. Hence the percentage of graphitic carbon in S1, and Sm is 13.33 and 21.18 percent respectively.

The results of the proximate analysis of samples of graphite ores carried out to determine the moisture content, volatile matter, ash and fixed carbon content are given in appendix-A.

The percentages of organic matter and non-graphitic carbon in graphite ores are given in appendix-B.

The results of the ash analysis of graphite ores carried out to determine Sio2, R CaO and MgO are given in appendix-C.

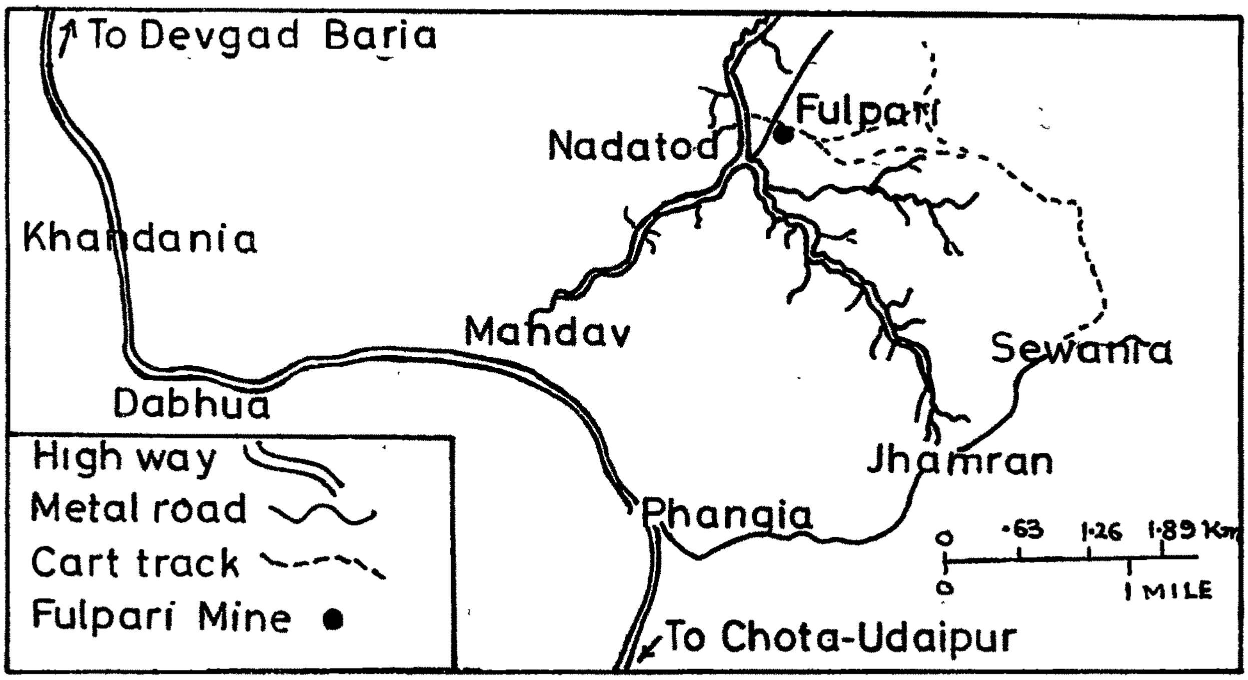
Beneficiation

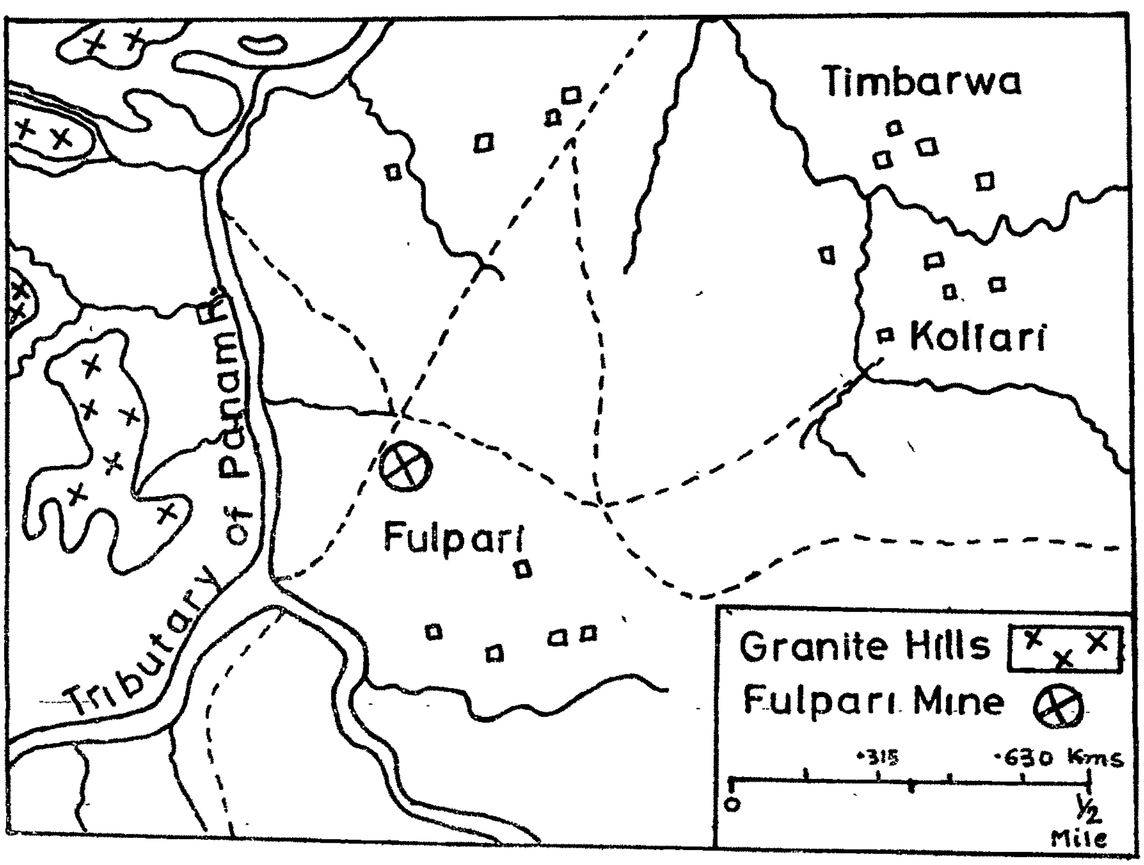
The run of mine graphite ore from Fulpari mine is transported by truck to Devgad Baria where Haswin Minerals have erected a beneficiation plant for graphite. The ore is friable and the size ranges from 2 cm. to 5 cm. The ore is ground by pulverizer to reduce the particle size to 150-250 mesh fineness to liberate graphite particles. Froth flotation method of concentrating graphite particles is used. The ground ore is mixed with water to form a pulp and pine oil is added as a collector in conditioning tank. The mixture flows to the flotation cell. Since pine oil is also a good frother no additional frother is required to be added in the flotation cell. The concentrate from the rougher flotation containing 52-55 percent graphite is dried under the sun by spreading it on the floor. The cleaning of the rougher concentrate is done by reflotation without further grinding. The cleaned concentrate contains 65-70 percent graphite.

Industrial uses

The concentrate of 'amorphous' graphite containing 52 to 70 percent graphite carbon is a valuable industrial raw material. It is an admirable material for foundry facings to which refractory clays for bonding and talc, sand and mica to improve the quality of the mixture may be added. It can be used as a lubricating agent where conventional lubricating oils and greases can not be used. Paints, pencils, carbon, brushes and dry-cell batteries can be manufactured from this graphite concentrate. The mixture of this fine grained graphite with coarse-grained graphite from some other places can be used to manufacture graphite crucibles.

LOCATION MAPS





FULPARI MINE
GRID REFERENCE – Z 954 880
TOPO SHEET NUMBER – 46 F/14

Profile Sections of Fulpari Mine

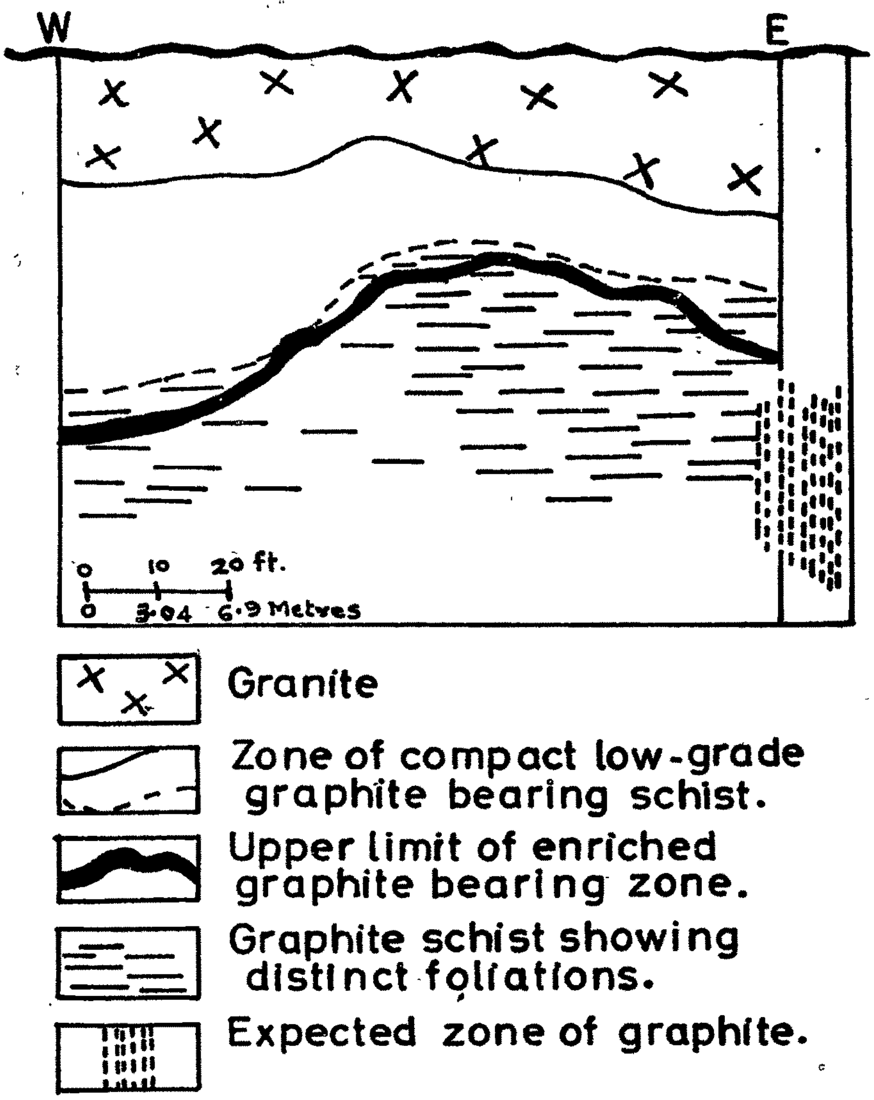


Fig.1
East West Section along Northern Flank.

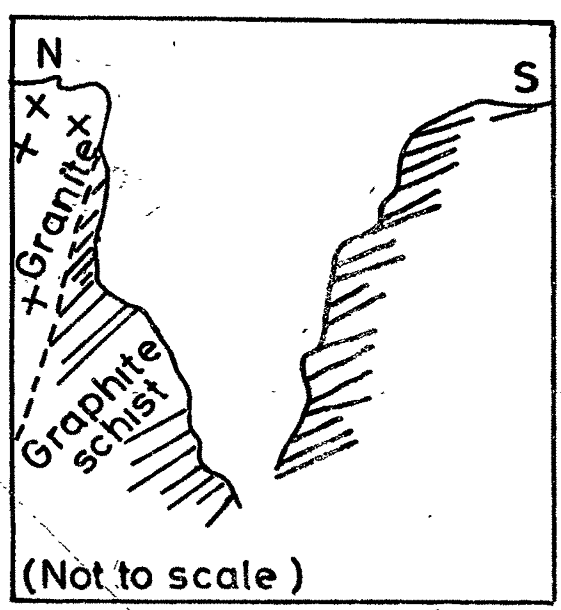


Fig.2.
North-South Section

Fig.1 Thin section of graphite schist.

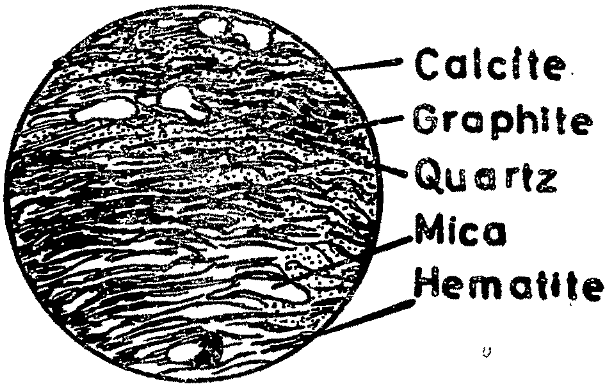


Fig.2 Thin section of graphite schist.

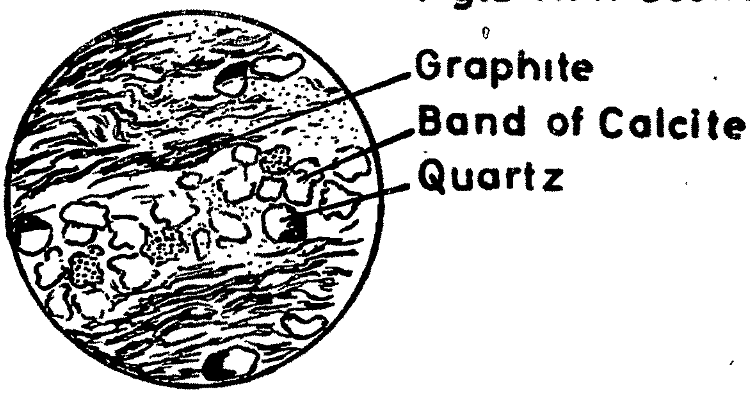


Fig.3 Thin section of graphite schist.

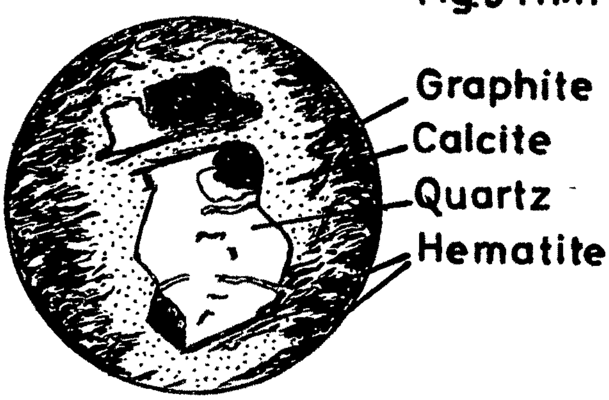
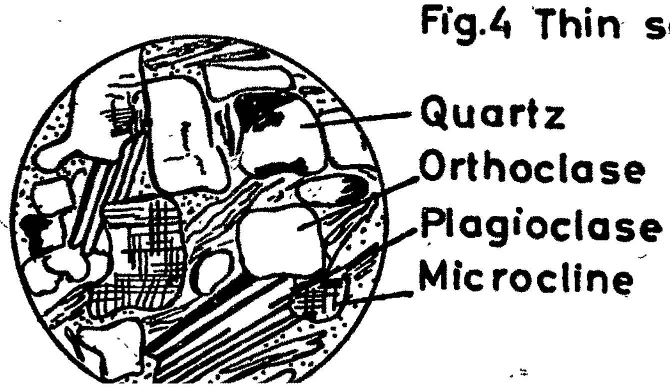


Fig.4 Thin section of granite.



APPENDIX--A

Proximate analysis of graphite ore.

Sample No.	Moisture 'M' % by wt.	Volatile matter 'VM' % by wt.	Ash 'A' % by wt.	Fixed carbon 'FC' % by wt. (by diff.)
S_1	2.14	4.25	75.38	18.24
S_2	2.9	5.98	77.4	14.39
Sm	2.15	4.48	70.12	23.00

APPENDIX--B

Organic matter and non-graphitic carbon in graphite ore.

Sample No.	Organic matter % by wt.	Non-graphitic carbon % by wt.
S_1	0.09	4.91
S_2	0.06	..
Sm	0.08	1.82

APPENDIX--C

Ash analysis of graphite ore.

Sample No.	'SiO_2' % by wt.	'R_2O_3' % by wt.	'CaO' % by wt.	'MgO' % by wt.
S_1	72.00	21.80	3.92	1.74
S_2	57.37	25.51	13.44	2.13

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BENEFICIATION OF LOW GRADE GRAPHITE ORE FROM BIRPUR, BARODA DISTRICT, GUJARAT STATE

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ABSTRACT

Beneficiation tests of low grade graphite ore from Birpur were carried out by Mr. Muley M.V., Jr. Research Fellow, in the Ore Dressing Laboratory of Bhabha Atomic Research Centre (B.A.R.C.), Bombay. The ore assayed 8% fixed carbon and with chief gangue minerals quartz, feldspar and micas. The liberation size for graphite was found to be minus 200 mesh (Tyler). The ore was crushed by a laboratory Jaw-crusher followed by Roll crusher. The crushed ore was wet ground in a laboratory Rod mill to prepare ore pulp for flotation tests. First, rougher flotation was carried out by using a mixture of diesel oil and kerosene as a collector and pine oil as a frother. The cleaning of rougher concentrate was carried out by adding only Calgon (sodium hexa meta phosphate) as a depressant. Two more cleaning operations were carried out without using any reagents. The final concentrate assaying 87% fixed carbon with a recovery of 98% is an accepted commercial grade.

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