Bulletin of Nepal Geological Society, 2018, vol. 35

Gypsum Prospects in Nepal and their Importance in Mineral Industries especially in Portland Cement Production

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ABSTRACT

Gypsum is one of the important nonmetallic industrial mineral which is commonly used with clinker to manufacture portland cement and also to make plaster of paris, wall boards, ceiling pans, medicine, fertilizer etc. Exploration of gypsum in Nepal has not got priority in the past although preliminary investigation of salt and detail investigation of limestone have been carried out since long time. Recent change situation in the country and ongoing process of industrialization especially establishment of many cement industries of various capacities based on own limestone deposits etc. the government of Nepal must give high priority to explore and mine gypsum in potential areas so that cement industries could sustain and flourished without any shortage of gypsum which is mostly imported from India and Bhutan.

Keywords: Gypsum, Industrial minerals, Portland cement, Plaster of paris

INTRODUCTION

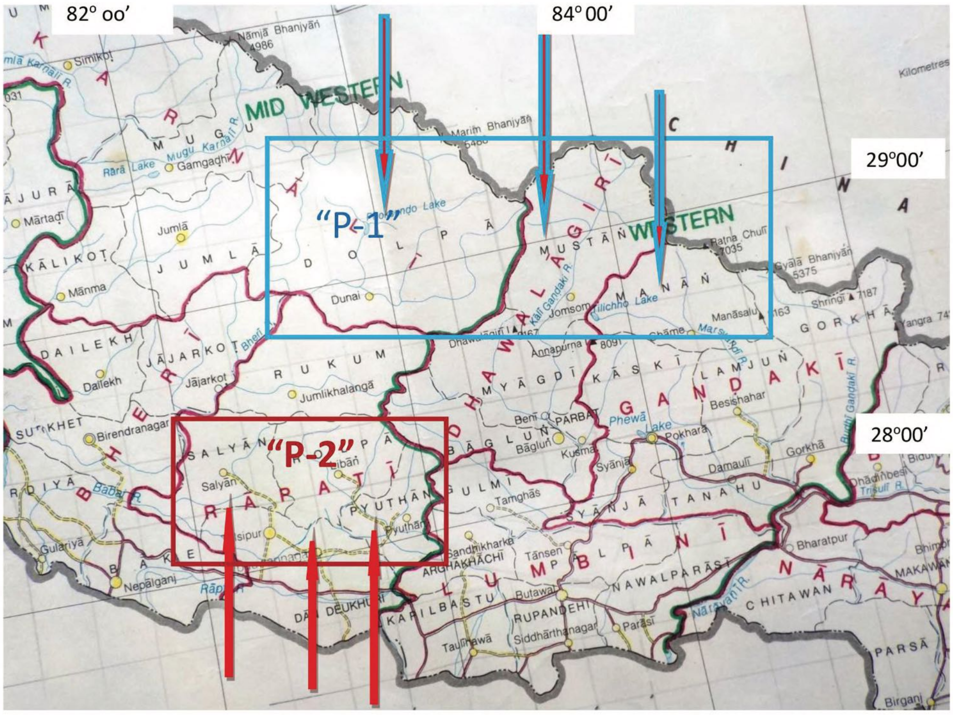
The name gypsum was derived from the Greek word gypsos = gypsum used as plaster. It is a common mineral widely distributed in sedimentary rocks and frequently occurs as interstratified with limestone and shale and usually found as layers underlying beds of rock salt. It occurs commonly as lenticular bodies or scattered crystals (incrustation) in fractured limestone and shale. It is also found in volcanic regions especially where limestone have been acted upon by sulfur vapors. Calcium sulfate is one of the principal evaporate which is formed as a result of evaporation of saline water. Generally gypsum in closely associated with anhydrite ($CaSO_4$) halite, calcite, sulfur, quartz and pyrite. Pure solutions containing calcium and sulfate ions will deposit gypsum ($CaSO_4.2H_2O$) below 42°C and anhydrite ($CaSO_4$) above this temperature. Presence of small amount of sodium chloride (NaCl) depresses this temperature considerably. Gypsum is a very important and essential constituent, besides limestone, which is the main rock to manufacture portland cement. It works as retarder in portland cement in which about 3 to 5% gypsum is required.

FAVORABLE GEOLOGICAL SITES FOR GYPSUM DEPOSIT

From the existing geological maps of Nepal prepared by Department of Mines and Geology (DMG) and other researchers one could hardly find suitable geological environment in the Lesser Himalaya and Higher Himalaya that is favorable for gypsum deposits except few minor indications as gypsiferous beds in the form of thin irregular layers/ lenses in limestone, shale and dolomite beds (Tertiary Age) in Kapurkot of Sallyan and in some parts of Dang area in the Lesser Himalaya (Kaphle, 2006, Bashyal, 1994), and brine water seepage and salt encrustation in shale and limestone of Tibetan Tethys sedimentary sequence in Tethys Himalaya/ Inner Himalaya (DMG, 2004, Fig.1). After literature review and preliminary investigation especially in Narsing Khola section and Chhiding Khola section and surrounding area which belongs to the Tibetan Tethys sedimentary rock sequence (Carboniferous to Cretaceous) in the north beyond South Tibetan Detachment Fault (STDF), it can be said that the middle and upper parts of Mustang could be the potential sites for gypsum exploration along with rock salt in the vicinity or within carbonate rocks and shale beds. Some brine seepages and salt incrustations exhibit the possibility of finding mineable size gypsum prospects since they generally occur together in many cases. Therefore, Government of Nepal/ Department of Mines and Geology must keep in high priority for systematic exploration of gypsum in this part of Tethys Himalaya covering Manang, Mustang and Dolpa districts.

ORIGIN AND ENVIRONMENT OF DEPOSITION

Gypsum occurs commonly in primary evaporite depositional environment. Both gypsum ($CaSO_4.2H_2O$) and anhydrite ($CaSO_4$) are mainly deposited by precipitation from aqueous solution when the concentration of the components and the physical conditions are quite suitable. Majority of such deposits are originated from evaporation of marine brines in arid (windy and dry) climate. In most cases, they are associated with salt deposits. Gypsum may also precipitate along the fractures, bedding planes or in other available spaces like cavities/ caverns where sulfate ion rich groundwater from the oxidation of sulfides comes into contact with carbonate rocks (Jorgensen, 1994). Precipitation of gypsum is possible where brine concentration is appropriate to recrystallize or dissolve



Area "P-2" Less prospective area (Priority P-2) Parts of Dang, Sallyan, Rolpa and Pyuthan districts

Area "P-1" More prospective area (Priority P-1 Parts of Manang , Mustang and Dolpa districts

Fig. 1: Prospective areas for Exploration of Gypsum and Rock salt in Nepal

readily as the metastable or temporary environment change.

The sedimentation of anhydrite generally takes place in a depositional basin because of water circulation between this basin and a small closed lagoon on the shelf. Seawater penetrating into the lagoon from the open sea expelled the brine formed by evaporation from it. Anhydrite deposition takes place from brine in the deep sea environment, e.g. in Delaware, Texas (Fig. 2), New Mexico, Louisiana, Ohio, New York in USA and Ontario in Canada (Kuzvart, 1984). The sequence of crystallization of salts from marine brines depends on the initial composition and quantity, temperature and time of evaporation. In this case sequence of precipitation is calcium- magnesium carbonate, gypsum, halite, anhydrite and polyhalite. Where as in natural water bodies like lakes with solar evaporation the sequence of precipitation and order of crystallization is gypsum, halite, anhydrite and epsom salt. Gypsum also occurs in minor amount in some igneous and hydrothermal deposits and by concentrations in residual soil or as filling of fractures and fissures in rock containing water and infiltration deposits. In dry desert climatic condition concretion of gypsum also takes place in weathered material overlying marl and limestone with gypsum intercalations like in eastern desert of Egypt. In sand and weathered material near the desert surface gypsum crystals are arranged into "desert roses". Gypsum caps of salt diapers represent another genetic type of gypsum deposit (Kuzvart, 1984). According to him at a low pressure zone near the earth surface (100–300 m) anhydrite can change into gypsum with a volume increase by 30% or so and most of the gypsum deposits were generated by hydration of anhydrite in the Quaternary period. The age of the gypsum deposits in the world ranges from the Cambrian to Quaternary.

In USA gypsum is exploited from more than 50 mines in 24 states from rocks of Silurian to Quaternary age which contain billion tons that is sufficient for hundreds of years supply at current rate of consumption. In Canada more than 9 deposits are known from 6 provinces and also at places in Mexico, Dominican Republic, Jamaica etc. Commercial gypsum deposits known from France, Germany, Austria and Britain are found mostly in Triassic rocks. In Russia the gypsum are recorded and mined from the rocks of Upper Cambrian to Tertiary age. In China huge amount of gypsum are mined from rocks of different ages. In most cases gypsum contains from 10 to 15% impurities, however, exceptionally pure gypsum has less than 5% impurities. Such impurities could be insoluble minerals like limestone, dolomite, anhydrite, silica and soluble evaporate minerals like chloride, halite, sylvite and hydrous but insoluble clay minerals.

Artificial gypsum is obtained as by-product in the chemical industries but it is poor in quality. Such artificial gypsum is produced in former Czechoslovakia, Japan and also in few other countries. Japan uses high amount of artificial gypsum in the world record.

Fig. 2: Veins of gypsum in Caprock Canyons State Park, Texas (Source Wikipedia)

OCCURRENCES, THEIR TYPES AND PROSPECTS

Gypsum generally occurs as a common mineral widely distributed in sedimentary rocks, and particularly associated with marine salt deposits. It forms as an evaporite mineral directly by evaporation or later by hydration of anhydrite. It is deposited from sea and lake water, as well as in hot springs. It frequently occurs interstratified with limestone and shale and mainly found as irregular lenticular bodies, layers or beds along with salt (rock salt) as deposited by evaporation of salt waters. Gypsum may also crystallize in veins, cavity or vugs forming stain spar. It is frequently formed by the alteration of anhydrite and also by the reactions between sulfuric acid and carbonate rock in oxidizing sulfide deposits. They can also form by the action of sulfurous volcanic gases on the surrounding carbonate rocks. At places they occur as efflorescence in mines and speleothems in caves. Mostly gypsum are associated with salt domes (Fig. 3) and salt encrustations in shale and carbonate beds (Kaphle, 2006 and 2014) and also associate with many minerals but more common ones are Halite, Celestine, Calcite, Aragonite, Anhydrite, Dolomite and Sulfur, rarely with Quartz and Pyrite. Other varieties of gypsum are: Stain spar is a fibrous variety of gypsum and has silky luster. Selenite is also a fibrous variety of gypsum, which yields broad colorless and transparent cleavage folia and it looks more or less like as mica. Alabaster is a compact, very fine grained, massive pure variety. Anhydrite ($Ca SO_4$) occurs more or less same geological environment and in same manner as gypsum and often associated with it but not common as gypsum. It is also found in associated rock beds like salt deposit in the cap rock of salt domes (Fig. 3) and in limestone. In some cases anhydrite is also found in the amygdaloidal cavities in basalt. Bassanite ($CaSO_4.1/2H_2O$) is a distinct intermediate phase between gypsum and anhydrite and it can be identified only by X-ray diffraction (Pedersen and Semmingsen, 1982) and careful petrographic study.

Gypsum is an economically viable mineral commodity and mined in many localities in the Himalayan Region especially in India, Bhutan and Pakistan. However, in Nepal gypsum has never got priority in exploration activities in the past. However, preliminary exploration works were able to trace some gypsiferrous beds and gypsum with salt encrustation in different part of Mustang district and Kapurkot etc. in Sallyan, Dang and Pyuthan districts in Midwestern Nepal (DMG, 2004). The gypsum recorded in this part of Nepal is much younger than the gypsum bearing horizons mined in India and Pakistan. In Nepal, there is poor occurrence in the form of irregular lenses and layers and so far not a single economic gypsum deposit is found. Previously it was a low priority mineral commodity for the government, beside that there was lack of road networks to advance extensive exploration in the Tethys Himalaya (Inner Himalaya). Now the situation has completely changed, some infrastructures like road are constructed, electricity lines are available, communication system is strengthen and the newly formed government is committed to exploit and utilize own natural resources and planning to change the existing mineral policy so that more private investors could come forward to invest in mineral sector. At the same time, tentatively 2.5 billion mt. cement grade limestone deposits are known only in the Lesser Himalaya of Nepal (Kaphle, 2006 and 2014) and quite a few cement industries are already established and few others are in pipelines based on these limestone deposits in different parts of the country. Without gypsum all these cement industries could not function at all and produce portland cement. Therefore, it is a high time to explore, identify the potential prospects and mine gypsum in the country so that the country can save not only foreign currency but also help to decrease the present trade deficit with India from where major amount of gypsum is imported.

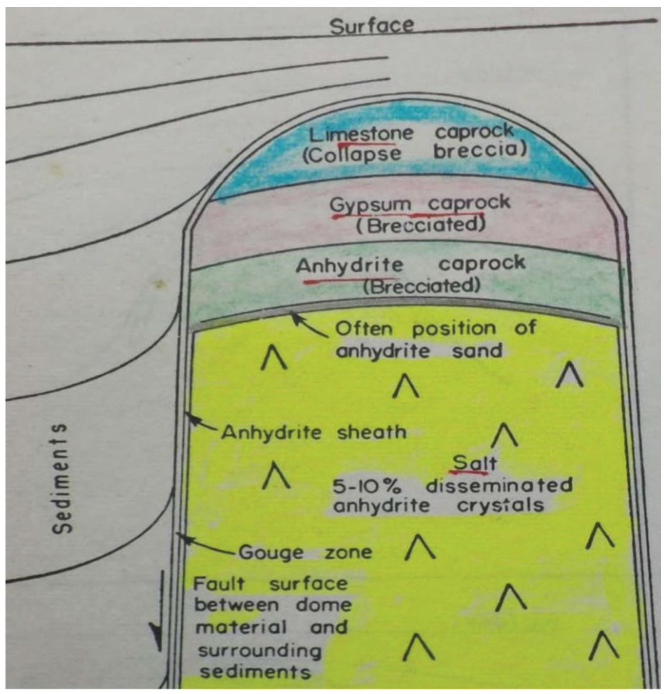


Fig. 3: Gypsum, anhydrite occurs as cap rock in salt dome. Diagrammatic cross section through a typical Gulf coast salt dome showing the component parts, (Lavorsen, 1972)

Fig. 4: Gypsum crystal (Source: Wikipedia)

Identification of Gypsum

Pure gypsum is a transparent colorless to white, gray, grayish white, occasionally with various shades of yellow, red to brown and becomes translucent (depending on the type and amount of impurities present) mineral (Fig. 4). It crystallizes in monoclinic system, mainly in prismatic crystal form or acicular (Fig. 5) and thin to thick tabular (010), fibrous (Fig. 6a and 6b), earthy, concretionary, granular or massive forms. They are coarsely striated, lenticular, rosettes (Fig. 7a and 7b), may be curved as well. Twinning is common by contact on (100) forming cruciform and v-shaped twins or rarely heart-shaped twins by contact on (101) (Deer, et al, 1966). Three sets of perfect cleavage (Fig. 4); vitreous or pearly and silky luster; splintery, parallel or conchoidal fracture; 2 hardness; 2.3 specific gravity, softness, flexible but not elastic or ductile are the diagnostic properties (Dana, 1959).

Fig. 5: Acicular, Pencil size crystals of Gypsum (Source: Wikipedia)

Under the microscope, in thin section gypsum is granoblastic, looks transparent to translucent, colorless or white; if colored by impurities it looks yellow, pink, reddish brown, brown or gray in transmitted light; none pleochroic, low relief (slightly lower than balsam); rather weak birefringence. Interference figure is biaxial positive with moderate axial angle and show strong dispersion, fluorescent and phosphorescent (Kerr, 1959).

With respect to chemistry or chemical composition, gypsum is a hydrous calcium sulfate ($CaSO_4 . 2H_2O$), when pure it consists of CaO = 32.6%, SO_3 = 46.5% and H_2O = 20.9%. It is soluble in hot dilute sulfuric acid (H_2SO_4). With barium chloride solution, it gives rise to white barium sulfate as precipitate. Since gypsum dissolve over time in water (slightly soluble in water) as a result sinkholes and caverns are developed in gypsum beds. Its properties like easy dehydration and rehydration make gypsum a valuable industrial and construction material.

Gypsum can be identified from other minerals including anhydrite by its physical, chemical and optical properties like softness, low hardness (can be scratched by finger nail), presence of three sets of prominent cleavages, soluble in hot dilute H_2SO_4 and presence of water, ductile and inelastic nature, etc.

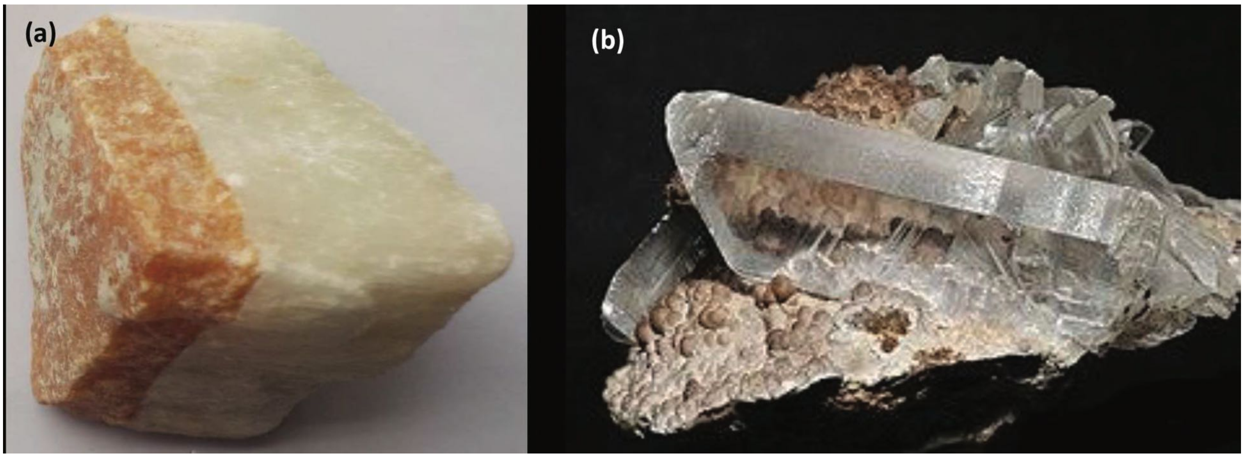


Fig. 6: (a) Fibrous gypsum (collected by K.P. Kaphle from German, 1986), and (b) Selenite from Mexico (Source: https://en.wikipedia.org/wiki/Gypsum#Uses)

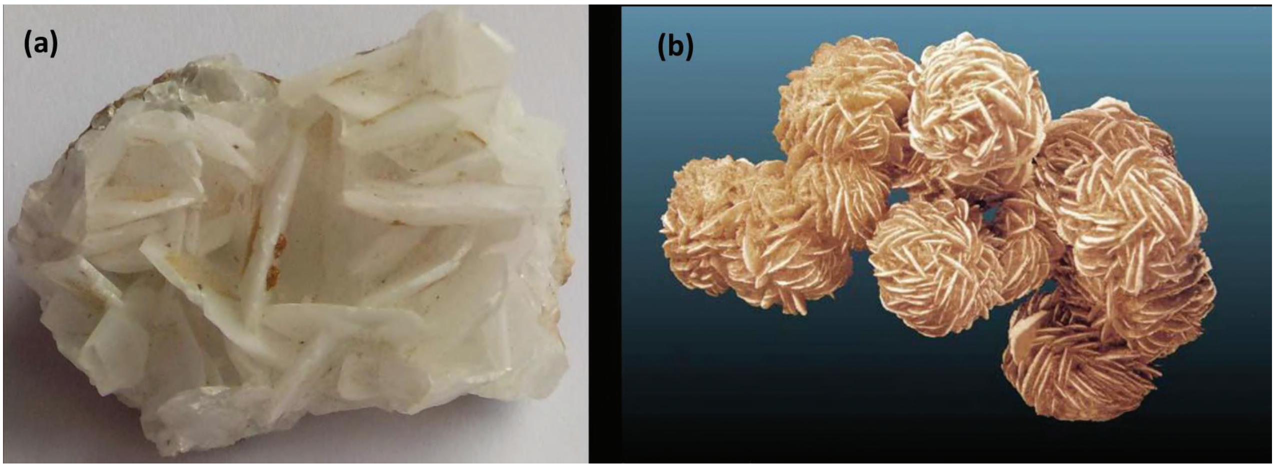


Fig. 7: (a) Rossette type of gypsum (collected by K.P. Kaphle from Australia, 1982) and (b) Desert rose, Bladded Rossette type gypsum (Source: website:https://www.industrialminerals)

WORLD SCENARIO OF GYPSUM DEPOSITS

Gypsum is one of the common sulfate mineral known from different parts of the world. It is mined and in more than 70 countries. Major gypsum producing countries are China, Iran, Thailand, USA, Turkey, Spain, Brazil, Canada, Mexico, Russia, Germany, Italy, UK, Australia, Japan, Indonesia, Saudi Arebia, Algeria, India, Pakistan etc. (Table-1). Large crystals in a cave complex in the Naica Pb–Ag mine, San Antonio mine, Santa Eulalia, Chihuahua in the El Teniente mine, South Wash and elsewhere in Utah, Great Salt Plains, Oklahoma; New Mexico etc. are the famous ones. Over 98 million mt gypsum was in production in above mentioned countries only (Jorgrnsen, 1994). From recent preliminary studies it is expected that the world annual production of gypsum is around 125 million mt. or so.

In Nepal Department Mines and Geology (DMG) did little preliminary exploration works for gypsum along with rock salt in Tertiary rocks of Dang, Sallyan, Rolpa, Pyuthan and Carboniferous to Cretaceous rock in Mustang and Dolpa districts (Fig.1). Such works were not able to trace gypsum mineralization bed as such except few minor occurrences like lenses or irregular gypsiferos layers. So far mineable/ commercial deposit is not reported in Nepal by DMG. In fact DMG has not taken it seriously to explore gypsum till today, although there is a high chance to find gypsum in association with salt encrustation in the Tibetan Tethys Sedimentary rocks like shale, limestone, dolomite (Carboniferous to Cretaceous) in Manag, Mustang and Dolpa districts (Aryal, 1973; Kaphle, 2006). Extensive systematic exploration of gypsum in these three districts, most probably lead to find the mineable size gypsum deposits. The demand of gypsum in the country is ever increasing extensively with the establishment of more than 25 cement industries and quite a few in pipelines. In spite of high demand of gypsum neither the Government of Nepal/ DMG nor any private sector or company is taking interest to explore and exploit gypsum in the country. Till today, all the internal demand of gypsum for

Table.1: Estimated production of Gypsum in 2015 (Source: USGS) (thousand metric tons)

Country	Production	Reserves
China	132,000	N/A
Iran	22,000	1,600
Thailand	12,500	N/A
USA	11,500	700,000
Turkey	10,000	N/A
Spain	6,400	N/A
Mexico	5,300	N/A
Japan	5,000	N/A
Russia	4,500	N/A
Italy	4,100	N/A
India	3,500	39,000
Australia	3,500	N/A
Oman	3,500	N/A
Brazil	3,300	290,000
France	3,300	N/A
Canada	2,700	450,000
Saudi Arabia	2,400	N/A
Algeria	2,200	N/A
Germany	1,800	450,000
Argentina	1,400	N/A
Pakistan	1,300	N/A
United Kingdom	1,200	55,000
Other countries	15,000	N/A
World total	**258,000**	**N/A**

cement industries and other uses are fulfilled by import from India and Bhutan. Every year about 400,000 to 500,000mt gypsum is imported for the cement and other industries.

EXPLORATION AND EVALUATION OF THE DEPOSITS

Exploration of gypsum is done by applying the same principle as for searching of other nonmetallic minerals. Before going to start an exploration program for gypsum the project geologist has to understand the regional geology, geology of the target area, geological environment of the deposition, possible origin and occurrence of gypsum and associated minerals in the rocks. For this first of all one has to review the exiting literatures related to evaporite, gypsum, anhydrite and salt deposits in the country and neighboring countries. By studying the geology one can establish the stratigraphy of the area. All the geological structures should be mapped to provide detail overview of the prospect area as a whole. All these information will help to correlate the lithology of the prospect area with the surrounding regions especially the lithological sequences of gypsum deposits known in the Himalayan countries and other countries. If there are some lithlogical similarities and indications of suitable evaporite depositional environment which is the prerequisite for gypsum deposit then only conduct detail exploration activities which can lead to find the economic gypsum deposits.

Geological mapping, close observation of outcrops and identification of various rock types (underlying and overlying rocks) help to trace the extent of gypsum mineralization band laterally and depth extension by drilling (large size borehole to obtain better core) which are the very first steps of detail exploration. In many cases studies of existing lithologs of oil and gas wells as well as ground water wells could also help to trace the deposits. Gypsum may occur as discontinues lenses but can extend for 10s of km, therefore exploration geologist must be aware of all about the nature of mineralization while geological mapping, calculating the tonnage and grade and evaluate the deposit for possible future mining. Geochemical exploration methods are not much applicable to look for gypsum deposits although high concentrations of sulfate in ground water might help as an useful clue to find out the possible anomalous areas. Similarly, Geophysical exploration is partially applicable to search for calcium sulfate and useful for determining lithological and structural details. Beside the quality and quantity the location of the deposit with respect to market is very important factor in the evaluation of a gypsum deposit since it helps to reduce the transportation cost from mine site to the market. It is a relatively low priced mineral commodity; therefore each deposit should be evaluated as per the market.

EXPLOITATION/ MINING

The mining geologists and mining engineers must calculate the overburden ratio in shallow or flat lying deposit and roof conditions in case of inclined deposit and underground mine. They must also consider the thickness of the mineralized bed, structural condition and possibility of unusual water conditions since they are related to capital investment and operating costs. As per the geological condition and the size, shape and grade of the deposit mining of gypsum can be done by developing simple open quarry or by underground mine. In first case draglines, excavators and scrapers are used to remove overburden if there is any and shovels and loaders to load the excavated materials. Rotary drilling with preferably large drill holes (50.8 to 101.6 mm diameter) are favored to collect the core samples and prepare lithologs (columnar sections) and laboratory investigations. For blasting explosive is used in ratio of 1 ton of rock to be broken with 1kg of explosive in average (Jorgensen, 1994). Cost and quality control are most important in mining. Underground mining of gypsum is generally done by room & pillar methods and about 25–33% material has to be left in pillars. In such case recovery/ mineable deposit of gypsum will be in 75–66% depending on the shape of the body and overlying and underlying rock types. Underground haulage can be done by rail, trucks or even by conveyor belts. Major gypsum producing countries are presented in (Table 1) Mining geologist and Mining engineer should always keep in mind that mining cost must be relatively low, long transportation and beneficiation of such low price mineral will increases the cost.

USE OF GYPSUM

Gypsum was used in Ancient Mesopotamia, Rome, Egypt since the Egyptian dynasties about 5000 years before present and the Nottingham alabasters in Medieval England. First production of gypsum in North America was started in Nova Scotia in 1735. Nova Scotia is the largest gypsum mining region in the world. In most of the countries uncalcined gypsum is blended with clinker (calcined cement grade limestone) and used as retarder to produce portland cement. Gypsum is a very fast setting material and used widely in the industries. It is light in weight, heat and fire resistance and low cost. With moderate heating gypsum is calcined and converted into the plaster of Paris, which is also known as hemihydrate ($CaSO_4.1/2H_2O$). When it is mixed with water it set as the calcium sulfate as stable dehydrated form. Gypsum is also used as filler in paper and various materials and in making adamant plaster for interior decoration and to manufacture wallboards, ceiling panels, tiles and fertilizer. It can be used to remove pollutants such asÊlead and arsenic from contaminated waters. Alabaster is used for sculpture since ancient time. Stainspar is cut and polished for various ornamental purposes. Beside these gypsum is also used in medicine, and manufacture ceramic casting forms. Both gypsum and anhydrite are the potential sources to produce sulfur and sulfur compounds (Jorgensen, 1994).

Gypsum block are massive building material composed of solid gypsum for building and erecting lightweight fire-resistant non-load bearing interior walls, partition walls, cavity walls, skin walls and ceiling panels. These blocks are composed of gypsum plaster, water and in some cases additives like wood fiber or vegetable for greater strength. Partition walls made from gypsum blocks require no sub-structure for erection and gypsum adhesive is used as bonding agent but not standard mortar. Waste gypsum boards previously used in wall, ceiling panels etc. can also be recycled and prepare virgin gypsum as raw materials to manufacture new products

CONCLUSION AND RECOMMENDATION

Gypsum is a common industrial mineral used as retarder in portland cement, in the production of plaster of paris for mold and casts and also in making adamant plaster etc. Nepal is still importing gypsum from neighboring countries to fulfill its internal demand. Now the time has come to replace import by own production. Therefore, it is highly recommended to explore and exploit gypsum in some potential areas in Tibetan Tethys Sedimentary Sequence in the Inner Himalaya.

Gypsum is mined since long time from the Himalayan Regions in India, Pakistan and Bhutan. Nepal lies in the central part of the Himalayan Range with similar geological rock units and geological structures, therefore there is a high possibility to find out gypsum deposits also in Nepal in the similar geological environment. DMG must be carried out extensive exploration in the possible prospective areas at the earliest for future mining.

Salt encrustations in highly jointed shale, limestone, dolomite in the Tibetan Tethys sedimentary sequences, and saline water (brine) seepages from them are quite common in middle and upper Mustang areas. The those areas, the local people used to extract salt (10 to 50 mt/yr) by aeration and drying brine water in the Narsing Khola and the Chhising Khola in Mustang district and Charkabhot Chorang area in Dolpa district. Since there is a high possibility to find out gypsum in association with salt deposits exploration for gypsum along with salt in such areas in Tibetan Tethys sedimentary sequence in Manang, Mustang and Dolpa districts is highly recommended.

Exploration and exploitation of gypsum in geologically potential areas where gypsiferous beds are known in different parts of Nepal must get high priority to exploit gypsum at least to fulfill the internal demand of cement industries. Possible gypsum occurrences in the geological formations identified in Nepal are quite younger than in the gypsum deposits known in India and Pakistan. Therefore, it is extremely important to look for the gypsum in the favorable similar rock units and geological environment as in other parts of the Himalaya.

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