Updated, for NGS website on 15 May 2020

MINERAL RESOURCES OF NEPAL AND THEIR PRESENT STATUS

Krishna P. Kaphle,
Former Superintending Geologist, Department of Mines and Geology, Kathmandu, Nepal
E-mail:kpkaphle@gmail.com

General Introduction

Nepal lies in the central part of 2500km long Himalayan belt. Almost 83% of Nepalese territory is mountainous. It is an underdeveloped, landlocked country situated in between China in the north and India in the south. Nepal is very rich in vast natural resources such as minerals, water, forest, medicinal herbs and varieties of agricultural products. For the economic development of the country exploitation and proper use of such valuable resources, especially mineral resources is extremely important. The mountainous region and the geological environment therein are suitable for metallic, nonmetallic and energy/ fuel mineral deposits as well as huge amount of construction materials, dimension and decorative stones. Continues efforts are required to find more mineral deposits in the unexplored virgin areas, early exploitation and sustainable development of known resources for the rapid economic growth of the country, provide job opportunities, and upgrade the quality of life and overall benefit to its people.

Minerals are the nonrenewable natural resources and hidden treasure of a country. They are mined and used in different forms for various purposes by the people since prehistoric time. Sustainable development of such resources play vital role to industrial development, employment generation, minimize dependency on foreign goods and services, save foreign currency, control trade deficit, strengthen the economy of the country and contribute substantially to national GDP. Systematic geological mapping, mineral exploration and detail investigation of mineral were started since the establishment of Nepal Bureau of Mines in 1961 (2018BS) and Nepal Geological Survey in 1967 (2024BS). Both of them were amalgamated by the Government of Nepal (GON) in 1977 and renamed it as Department of Mines and Geology (DMG). Mineral exploration activities were in peak during 1969 – 1984 when DMG and UNDP funded projects (1969 - 1972), Mineral Exploration Development Project (MEDP, 1974 -1978) and follow up works by DMG were in action. All these investigation/ exploration activities in the past were able to delineate quite a few prospective areas and also able to identify some economic and sub-economic mineral deposits in different parts of the country *(Fig.1).* Systematic petroleum exploration by DMG was started in 1979. First Airborne Magnetic survey over 48000sq.km area covering Terai and Siwalik belts was conducted with the help of IDA/ World Bank. The result of this survey was encouraging and the GON has established Petroleum Exploration Promotion Project (PEPP) in 1984 to promote and monitor the exploration works in the country. DMG/ PEEP has divided the area into 10 prospecting blocks for petroleum exploration in southern part of the country covering the whole Terai plane and major parts of Sub-Himalaya (Siwalik foot hills). The Government of Nepal invited foreign oil companies by opening for bidding exploration acreage in 1985 for the first time to explore petroleum in Nepal. Five foreign companies showed their interest and signed agreement with GON in different years (time) but except Shell Nepal BV none of them did extensive exploration work to find out the petroleum reserve in Nepal. All of them left Nepal when GON cancelled their petroleum agreements. Now the GON should understand the importance of the minerals and petroleum resources and give high priority in exploration, evaluation and sustainable development of industrial minerals, high price metals, base metals, precious and semiprecious stones, fuel minerals and petroleum and natural gas and mine/ exploit them at the earliest. GON must invite potential national and international investors/ companies to invest in mineral and mining sector as well as petroleum sector to establish mineral and petroleum industries by giving more incentives to attract them in the initial 3 to 5 years. Since last few years just over 550 private investors have shown their interest and involve in mineral exploration and mining activities. In FY 2075/076BS (2019) they obtained 388 prospecting licenses to explore 16 minerals and 143 mining licenses to mine 17 mineral commodities from DMG. Mineral exploration activities by DMG as well as by private sectors are going on but in very slow speed. Most of the mining license holders are reluctant to develop the mines (except some cement grade limestone) timely and properly by hiring trained technical manpower, purchasing suitable mining equipment and creating better mining environment. Most of the mines are in development stage with very slow progress and only some limestone and few dolomite, talc, calcite, marble, granite, quartzite, slate, coal, red clay, and semi-precious stones mines are in operation whereas magnesite, lead, zinc, copper and iron ore mines are still unproductive. Based on these mineral raw materials quite a few cement industries and very few marble, dead burnt magnesite (DBM), talcum powder, gemstone cutting & polishing, agri-lime, porcelain, pottery and rock slab cutting and polishing industries have been established but most of them are not in regular production and some of them are already closed due to lack of infrastructures, trained technical manpower, suitable mining equipment,

unavailability of raw materials, haphazard mining activities, environmental issues raised by local people, contradiction in Mines and Mineral Act, Forest Act and Local Governance Act related to ownership of natural resources, as well as many demands from the local people. Mineral resources and petroleum play vital role in the industrial development and it could contribute substantially (>15%) in the national GDP.

Mining History

Nepal has over 200 years long history of indigenous mining activities. Small scale historical iron, copper, lead, zinc, cobalt, nickel mines and placer gold panning in the major rivers and many slate, quartzite, dolomite and limestone quarries were operational in many districts. Old working pits, adits, smelting places, scattered slag and remnant of mine materials stand as solid proofs of such mining activities in the past. In many cases the name of the village is derived after the particular mines e.g. Taba Khani, Falam Khani, Shisa Khani, Sun Khani etc. Before 1951(2007BS) Nepal was one of the exporter of iron and copper to Tibet and cobalt to India. A gun factory based on Thoshe iron deposit was established in 1921 at Thoshe Megchan in Ramechhap *(Rana, 1965).* Its remnants still exist there. But after the change in the government in 1951 such mining activities were gradually closed because of change in the policy of new government, unavailability of charcoal for smelting, technical difficulties in mining at depth etc. Therefore, reassessment and evaluation of such deposits/ mines by DMG and/ or by private sector are extremely warranted for further exploration and mining. One of the examples is Thoshe iron deposit (old working mine) which was reassessed by DMG *(Kaphle & Khan, 1996, 2006)* and later explored in detail by N & C Minerals Pvt. Ltd. It has prepared a mining plan and obtained the mining license from DMG but it is still unable to develop mine and exploit the iron ore due to many complexities in getting permission from Department of Forest, lack of infrastructures, support from central and local government, huge amount of investment required to purchase mining equipment, hire well trained technical manpower and sustainable mine development without any environment damage and also decrease in international price of iron ore. Currently the company is in the process of mine development to exploit iron ore in near future. Now GON/ DMG is in the process to mine Dhauwadi – Pokhari hematite ore deposit in Nawalparasi for iron and also continuing petroleum and natural gas exploration in Dailekh.

General Geology and Mineral Resources

Nepal occupies the central part (one third) of east – west extending Himalayan range which is comparatively a younger mountain. Geology of Nepal is very complex because of continues geodynamic process in the Himalayan region that resulted many thrusting, faulting, folding, and suffered from magmatism and metamorphic events in the geological past. Geologically Nepal Himalaya can be simply divided into five distinct morpho-geotectonic zones separated by four prominent linear structures like Main Frontal Thrust (MFT), Main Boundary Thrust (MBT), Main Central Thrust (MCT) and South Tibetan Detachment System (STDS), from south to north. From mineral resources point of view, the southernmost Terai Plain (northern fringe of Indo Gangetic plain) area is potential for gravel, sand, ground water, and underlying Siwalik and Pre-Siwalik rocks below the Quaternary sediments at depth consists of stratigraphic and structural traps suitable for petroleum and natural gas reserves. The Sub Himalaya (Siwalik Foothills/ Churia Range including Dune Valleys) is the potential area for construction materials, radioactive minerals, minor amount of low grade coal seams, and possible reservoir rocks and structural traps for petroleum, natural gas. Similarly, the Lesser Himalaya (Mahabharat Range including Midland/ Valleys) is promising for metallic minerals mainly iron, copper, lead, zinc, cobalt, nickel, tin, tungsten, molybdenum, gold, uranium rare metals and so on; and industrial minerals like magnesite, limestone, dolomite, talc, phosphorite, bauxite, clay, kaolin, graphite, mica, quartz, silica sand and gemstones; fuel minerals such as coal, lignite, peat, methane gas, petroleum and natural gas; hot springs; radioactive minerals; and voluminous construction materials; crushed gravel as well as river boulders, gravel and sand etc. Some of the areas in Higher Himalaya are quite promising for precious and semiprecious stones, marble and metallic minerals like lead, zinc, uranium, gold, silver etc. Towards far north the Tibetan Tethys Zone (Inner Himalaya) is prospective for limestone, dolomite, gypsum, salt (brine water), radioactive minerals and natural gas. Because of difficult mountain terrain, complex geology, lack of infrastructures and financial constrain, exploration and exploitation of these mineral resources still challenging.

Mine Administration and Licensing System

In Nepal, all the mineral resources that occur in the country are owned by the state. DMG under the Ministry of Industry (MOI) is the responsible government organization which not only conducts systematic geological mapping,

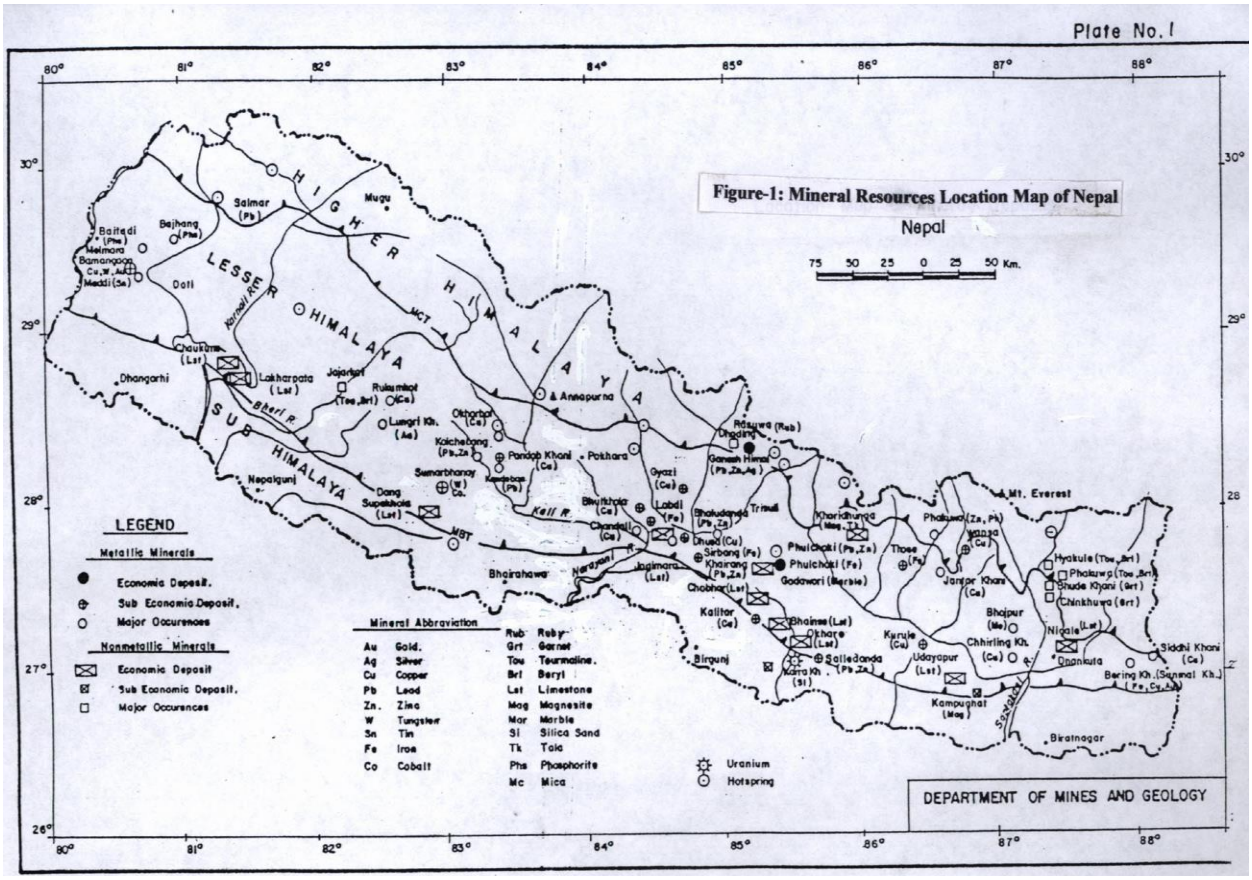
mineral exploration activities throughout of the country and petroleum exploration in selected areas but also administrates and fully exercises the Mines and Mineral Act 2042BS (amended in 2050BS) and Regulation 2056BS with amendments in 2060, 2072 & 2073BS and Nepal Petroleum Act 2040BS (1983) and Petroleum Regulation 2041BS (1985) with amendments in 1985, 1989, 1994 & 2018. Under these existing Rules and Regulations DMG issue both Prospecting and Mining Licenses and sign petroleum agreements with the interested national and international investors/ companies and regularly inspects and monitors the prospecting and mining activities carried out by the lease holders. DMG had issued about 121 and 142 mining licenses for 16 and 18 mineral commodities and about 365 and 388 prospecting licenses in FY 2074/75BS and 2075/76BS respectively. But only slightly more than half of them are in mine operations/ production and the rest still in mine development stage.

Mineral Deposits, Mines and Their Present Status

In course of time Geological investigations and mineral exploration activities carried out mainly by DMG since its establishment in 1961 till present and partly by DMG/ UNDP (1969 - 1972), UNDP/ DMG/MEDP projects (1974 - 1978) and Geological Survey of India (GSI, 1964-1968) and very few private entrepreneurs were successful to identify metallic, nonmetallic and fuel mineral deposits/ prospects/ occurrences and categorized as economic, sub-economic and noneconomic deposits of more than 66 mineral commodities in Nepal *(Fig.1. 2, 3 & 4).* Based on some economic deposits DMG is able to promote few mineral based industries like cement, agri-lime, marble, talc, dead burnt magnesite, zinc-lead, coal, gemstones etc. Few small to medium scale mines of limestone, magnesite, marble, talc, coal, peat, clay, salt, mica, quartz crystals, semiprecious and precious stones, dimension/ paving stones, roofing slates are in operation by the private entrepreneurs after obtaining the licenses from DMG. There are over 48 limestone quarries/ mines from which limestone are supplied to different cement industries. 7 gemstone (tourmaline, kyanite, quartz crystals), 1 iron, and few talc, coal, marble, red clay, calcite, quartzite, dolomite mines are in production (*www.dmgnepal.gov.np).* Few gem industries which do only cutting and polishing of semiprecious and precious stones from Nepal and abroad are established. Most of the minors they sold their raw materials to different industries. Construction aggregates, sand, gravel, dimension stone, decorative stones, paving stones and roofing slates are the other important mineral resources which have high demand for infrastructural development works are locally mined. Metallic ore minerals of iron, copper, lead, zinc, cobalt, nickel, tin, tungsten, molybdenum, and placer/ primary gold are also known from different parts of Nepal but they are not yet mined systematically. Previously two placer gold mining license were issued to private sector but they did not show any production for long time and closed. N & C Minerals Pvt. Ltd. a private company obtained mining license to mine Thoshe iron deposit from DMG but not yet in production. Similarly another Pvt. Co. has obtained a mining license to mine copper ore from Bamangaon polymetallic deposit but its progress is very slow even in preparation of mine plan and mine development. Recently, DMG is in the process to mine Dhauwadi – Pokhari hematite deposit in Nawalparasi. DMG has already proved 310 million m^3 methane gas reserve in Kathmandu valley which can be utilized for house hold use to replace imported propane gas. Major and important mineral prospects are briefly described below.

DMG has also started systematic petroleum exploration work since 1979. Natural gas and oil seepages in Padukasthan, Sirsasthan, Navisthan etc. in Dailekh and gas seeps in Muktinath in Mustang are the direct signature of the existence of hydrocarbon/ oil and natural gas in Nepal. In addition to that, shale beds of Lakharpata, Gondwana and Surkhet Group are found to contain 2 – 20% Total Organic Carbon (TOC) which is another strong evidence of petroleum occurrences. In regional context, existence of petroleum in Potwar Basin in Pakistan in the west and in Aasam Basin in India in the east are other positive indicators that support to high possibility to find out similar oil reserve in the similar geological environment/ lithological horizons in Nepal. Considering these evidences geological, aeromagnetic, gravity and seismic survey covering 48,000km^2 area was conducted by DMG in 1978-79 with the help of IDA/ World Bank. Petroleum Exploration Promotion Project (PEPP) was established under MOI/DMG in 1982 to promote and monitor the exploration works. Petro-Canada and Compagnie General De Geophysique (CGG) did seismic survey over 3000km^2. Hunting Geology and Geophysics Ltd. conducted photogeological study over 60,000km^2 area covering Terai and the Siwalik. These studies helped to divide the southern part of the country covering the Terai plane and Siwalik Foothills into 10 petroleum exploration blocks like Block.1 (Dhangari), 2 (Karnali), 3 (Nepalgunj), 4 (Lumbini), 5 Chitwan), 6 (Birgunj), 7 (Malangwa), 8 (Janakpur), 9 (Rajbiraj) and 10 (Biratnagar) *(Fig.5)*, each with approximately 5000km^2 area www.petroleumnepal.gov.np. The GON/ DMG/PEPP opened for bidding exploration acreage in 1985 for the first time and invited foreign oil companies to explore petroleum in Nepal with a view to promote petroleum exploration and establish petroleum industries. First of all, Shell Nepal B.V/ an oil company from Netherlands and Triton Energy Corp, USA (1986-1990) jointly acquired the block-10, Biratnagar to explore petroleum. It has conducted detail exploration by gravity

and seismic survey (covering 2000 line km.) and also did petroleum exploration drilling up to a depth of 3520m to test hydrocarbon potential in this block. But the hole appeared dry and then the company left Nepal for good in 1990. After that, Texana Resources Co. (USA) (1998) acquired block-3 (Nepalgunj) and 5 (Chitwan). This Co. did only preliminary field study and some laboratory tests of the selected samples. But the work was not satisfactory as per the agreement. Similarly CAIRN Energy PLC (UK, 2004) leased five blocks as Block no.1 (Dhangari), 2 (Karnali), 4 (Lumbini), 6 (Birgunj) and 7 (Malangwa). It had established an office in Kathmandu and also did some field investigations and laboratory tests of few possible source and reservoir rocks samples but most of the time they remained reluctant to conduct extensive field works, as a result there was no significance progress in petroleum exploration sector in spite of government's high priority. GON cancelled their lease contract and both Texana Resources and Cairn Energy left Nepal in 2014 without any finding. In 2012/2013, An Arabian oil companies named as Emirates Associated Business Group (EABG), UAE leased block 8 & 9 and USA based BBB Champions oil co. Inc. leased block-10 to explore petroleum in Nepal, but they did not start exploration works seriously and left Nepal within less than two years. Recently GON/ DMG/PEPP with the technical cooperation of People's Republic of China has started detail exploration of petroleum and natural gas in Dailekh. So far seismic survey (200 line km in 400sq km area supported by magneto telluric survey and collection of source rock samples and soil samples are completed. Laboratory investigation and chemical analysis of the samples and interpretation of seismic data are in process in China. Preliminary field data appear interesting *(PEPP, Tripathi, 2019).*



(A) Metallic Minerals

Metallic minerals are very much used in various purposes in our day to day life. They are extracted from their respective ores. Gold, platinum, silver, copper and mercury also occur as native state. A numbers of metallic ore minerals are known to exist in different parts of Nepal but only the important ones are briefly described here.

Iron (Fe) is the principal metal which is used extensively in infrastructure development works, and to manufacture steel, heavy machinery equipment, arms, agricultural tools etc. Iron ores like magnetite (Fe_3O_4), hematite (Fe_2O_3), limonite/goethite ($FeO(OH).nH_2O$) and siderite ($FeCO_3$) occurrences/ prospects/ deposits are known to exist in more than 88 localities. Some of these ores were extensively mined and smelted in different parts of Nepal for more than

100 years till 1951 (2007BS) but none of these mines are in operation since then. The well known iron ore deposits are Phulchoki (Lalitpur), Thoshe (Ramechhap, *Fig.2A*), Labdi Khola (Tanahun), Jirbang (Chitwan), Dhauwadi - Pokhari (Nawalparasi), Falamkhani/ Dhuwakot (Parbat), Bhedikhor and Lukarban (Baglung), Purchaundi/ Lamunigad (Bitadi), Dahabagar, Kachali, and Ekghar/ Khanigaon (Bajhang). Iron prospects and old workings are also known from different parts of Baitadi, Bajhang, Jajarkot, Rolpa, Surkhet, Myagdi, Baglung, Parbat, Chitwan, Ramechhap, Okhaldhunga and Taplejung districts *(Kaphle, 2018).* Phulchoki iron deposit still remained untransformed into commercialization due to its location in the environmentally sensitive area and also shortage of power like electricity and unavailability of good quality coal in Nepal. Thoshe iron deposit was mined in small scale during Rana's regime for more than 100 years till 2007BS. But it was totally stopped after 2007BS. DMG *(Kaphle & Khan 1996. 2006)* did the assessment of this prospect and calculated geological reserve of about 10.5 million ton iron ore. Further extension of the area and detail exploration by N & C Minerals Pvt. Ltd. has estimated about 15.9million ton iron ore with an average grade 45.3%Fe *(Kaphle, 2011)*. DMG issued 7 prospecting and 4 mining licenses to the private/ public companies in FY 2018 *(DMG, Annual report, 2019).* DMG is in the process to mine Dhauwadi – Pokhari hematite ore deposit in Nawalparasi.

Fig.2A: Iron Ore from Thoshe

Fig.2B: Bamangaon polymetallic deposit

Fig.2C: Bhutkhola Copper deposit/ old working

Copper (Cu) is another very important metal which is mainly used in electrical industries for the production of electrical and electronic equipment/ goods, copper wires, coins, crafts, making alloys, containers and utensils for household purposes. It was mined traditionally in Nepal since historic time but at present there is no running copper mine as such. The common copper ore found in Nepal are chalcopyrite ($CuFeS_2$), malachite ($CuCO_3(OH)_2$), azurite ($Cu3(CO_3)_2(OH)$, covellite (CuS), cuprite (Cu_2O), bornite (Cu_5FeS_4), and chalcocite (Cu_2S). Copper ore deposits/ prospects/ occurrences are known from more than 107 localities in the country. Small scale copper mines were in operation in Gyazi (Gorkha), Okharbot (Myagdi) and Wapsa (Solukhumbu) till 1995 and they were able to produce 20 to 50mt finished copper per year. Other copper prospects/ deposits like Kalitar (Makwanpur), Dhusa (Dhadhing), Wapsa (Solukhumbu), Bamangaon (Dadeldhura, *Fig.2B,* Bhut Khola (Tanahun) *Fig.2C)*, Khandeshori - Danfechuli/ Marma (Darchula), Pandav Khani (Baglung), Baise Khani (Myagdi), Ningre (Myagdi), Mul Khani (Gulmi), Sikpashore (Dolakha), Kurule (Udayapur), Chhirling Khola (Bhojpur), Janter Khani (Okhaldhunga), Siddhi Khani (Ilam) are the major ones. Many scattered old workings are also known from different parts of Darchula, Bajhang, Bajura, Parbat, Baglung, Myagdi, Gulmi, Tanahun, Gorkha, Makwanpur, Kavre, Ramechhap, Okhaldunga, Dhankuta, Solukhumbu, Ilam and Taplejung districts. 1 mining license and 7 prospecting licenses for copper have been issued by DMG *(DMG, Annual report, 2019).* At present not a single copper mine is in operation/ production.

Zinc (Zn) and Lead (Pb): Occurrences/ prospects/ deposits of lead and zinc are reported from more than 57 localities in different parts of Nepal. In most cases their ore minerals like Sphalerite (ZnS) and Galena (PbS) are associated and occur together like in Ganesh Himal area (Rasuwa), Phakuwa (Sankhuwasabha), Labang- Khairang (Makwanpur), Pangum (Solukhumbu), Salimar valley (Mugu/ Humla), Daha Gulzar and Rani Shikhar (Darchula), Phulchoki (Lalitpur), Hatti Lekh (Palpa), Sisha Khani and Kandebas (Baglung), Dhuwakot (Parbat), Barghare (Makwanpur) and Khola Khani (Taplejung). Most of them are known as old workings. Among them, only Ganesh Himal Zinc - Lead deposit (at Lari, Serkaping, Suple, Poktanzo) have been explored in detail. Lari deposit is an economic deposit of about 2 million mt. ore with combined grade 13% Zn+Pb with minor Ag and Cd. An underground mine has been development by Nepal Metal Company long time before but the deposit still remained unexploited due to its remote location without road approach, harsh climate, complex geology, small tonnage in spite of its high grade, and other technical and financial reasons. However, detail exploration and evaluation of nearby Serkaping, Suple and Poktanjo Pb+Zn prospects could also be economic deposit and mine together with Lari deposit. DMG issued 1 zinc and 3 lead mining license and 1 zinc and 2 lead prospecting license in 2018 *(DMG, Annual report, 2019)* to the private investors but so far none of them are in operation and production.

Cobalt (Co) prospects are not as common as iron, copper, lead and zinc in Nepal. Cobaltite (COAsS) and erythrite ($CO_3(AsO_4)_2.8H_2O$ are the two common ores of cobalt. In vein type deposit it occurs with nickel minerals. 70% Co comes from Congo. Few old workings and test mining for cobalt were carried out long time before from Netadarling & Tamghas (Gulmi) and Samarbhamar in Arghakhanchi districts and the ore used to export to India. They are also recorded from Lamadanda (Dhadhing), Nangre (Kavre), Bhorle (Ramechhap) and Bauli Gad (Bajhang) districts. Reassessment by detail exploration and evaluation of these prospects is required to confirm the grade and tonnage of the deposits. There is no cobalt mine in operation at present. It is one of the important metal in modern age. It is mostly used to make battery for electric vehicles and pigment to produce blue glass and in polishing diamond. Both Co and Ni are harmful to health to develop cancer, chronic bronchitis etc.

Nickel (Ni) is a silvery white shining metal with a slight golden tinge. Its occurrences are reported from few polymetallic deposits like in Bamangaon (Dadeldhura), Bering Khola – Sunmai (Ilam), Bauligad (Bajhang), Khopre Khani (Sindhuli) and old workings from Nangre (Kavre), Bhorle (Ramechhap) and Ningre (Kavre) areas *(Sharma,1966).* The main ores of this metal are niccolite (NiAs) and pentlandite $(Fe,Ni)_9S_8$) which are mainly associated with chalcopyrite, pyrrhotite and pyrite. Follow up and detail exploration is required to confirm the overall tonnage and grade of these known occurrences. At present not a single nickel and cobalt mine is in operation. Nickel and chromite both are used in chrome steel and other alloys to withstand high temperature and corrosion. It is also used in batteries. Nichrome is used for resistance in electrical heating equipment.

Gold (Au) is a precious attractive yellow metal which has very good market price worldwide. Its present price in world market is increasing since last few months and now reached around US$1725/ounce. It is widely used in making coins, ornaments, jewelry, dental appliances, electroplating, metal coating and many other purposes. In Nepal alluvial/ placer gold are frequently wined by local dwellers (Botes) from the river gravel/ sediments deposited by the major rivers like Mahakali, Chamliya, Jamari Gad, West Seti, Karnali, Bheri, Rapti, Lungri Khola *(Fig.3A*), Phagum Khola, Kaligandaki *(Fig.3B),* Myagdi Khola, Modi, Madi, Marshyangdi, Trishuli, Budhigandaki, and Sunkoshi Rivers along their high and low flood plains as well as in their terraces *(Kaphle, 1996).* Placer gold in these rivers are mainly derived from higher Himalayan region *(Sthapit & Kaphle, 2005)*. Primary gold in-situ occurrences are known from Lungri Khola area *(Joshi, 1991,* in Damphutar, Dokadhunge, Phuliban, Sherma, and Gam (Rolpa); Bangabagar, Gorang & Jamari Gad (Baitadi); Bamangaon (Dadeldhura), Khandeshori (Darchula), Upper part of Bauligad (Bajhang) and rarely in Bering Khola – Sunmai area (Ilam). Gold is generally found in association with silver and many other sulphide ores (Chalcopyrite, Arsenopyrite, Pyrite) mainly in hydrothermal quartz veins, quartz sulphide veins and in auriferous quartzite. Exploration works in the past have shown high possibility to find primary gold in the Higher Himalayan region. Therefore, all these known occurrences must be well evaluated to confirm the deposits. 2 mining licenses and over 30 prospecting licenses for placer gold exploration have been issued by DMG in FY2012/13 but at present not a single license is renewed/ issued.

Fig.3A: Placer gold from Lungri Khola, Rolpa

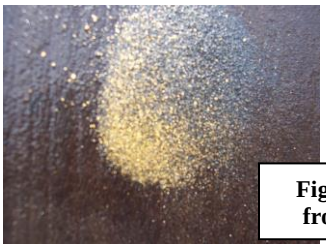


Fig.3B: Placer gold from Kaligandaki

Silver (Ag): Argentite (Ag_2S) is the chief ore of silver. It is also widely used in making coins, ornaments, jewelry, dental appliances, crown, utensil, and in many other purposes. Silver ore are generally associated with gold, cobalt and zinc-lead ore. Silver is soft, shining and heavy metal. In Nepal minor amount of silver is reported in the zinc + lead ore of Ganesh Himal (Rasuwa), Barghare (Makwanpur) and polymetal sulphide of Bering Khola – Sunmai area (Ilam), in association with cobalt ore in Netadarling (Arghakhanchi) and Samarbhamar (Gulmi) but none of these appeared as economic deposit suitable for silver mining. However, it is possible to extract Ag as byproduct while mining gold and sulphide ores of lead, zinc and cobalt.

Tin (Sn) mineralization are normally reported in the vicinity of granitic rocks especially at the contact zone in the gresinized part and in pegmatites. Cassiterite (SnO_2) is the main ore of tin which is recorded at Meddi and Ganera in Dadeldhura, and Mandu Khola area in Makwanpur districts. At Meddi there are numerous thread like irregular veins

or irregular patches of in-situ cassiterite – quartz or quartz + cassiterite + pyrite mineralized veins *(Kaphle & Joshi, 1982).* Cassiterite rich floats are seen in Meddi Khola sediments but there is no significant economic deposit suitable for mining. Tin is extracted from its ore cassiterite and mainly used to manufacture tin metal and tern plate for food containers, to coat other metals to prevent corrosion, with lead in solders, and alloy with copper and antimony.

Tungsten (W) is a very important metal/ element with high melting point. It is chiefly used as filaments in electric bulbs, cathode ray tubes, hardening metals to manufacture high speed cutting tools, tungsten carbide drill bits, springs, chisels, files, armory etc. Sodium tungstate is used in fireproofing cloth. Scheelite ($CaWO_4$) and wolframite ($(Fe,Mn)WO_4$) are the common ores of tungsten. In Nepal scheelite occurrences are known from Bamangaon polymetallic deposit *(Kaphle, 1997)* and few minor occurrences in other places of Dadeldhura and Makwanpur.

Molybdenum (Mo) occurrences are reported from Khari Khola (Solukhumbu), Bamangaon (Dadeldhura), Bauli Gad (Bajhang), Lungri Khola (Rolpa), Samarbhamar (Arghakhanchi) and Chau Khola (Makwanpur). Molybdenite (MoS_2) is the chief ore mineral, however, it is also derived from Wulfenite ($PbMoO_4$). It occurs mainly in quartz veinlets in granites/ pegmatites with fluorite and topaz and also associated with scheelite *(Kaphle, 1997).* It is used in electronics as a semiconductor and transistor material as well as in the petroleum industries.

Chromium (Cr) can be extracted from its ore mineral Chromite ($FeCr_2O_4$). It is mainly associated with ultrabasic and basic rocks like norite/ gabbro. Chromium is used as a ferroalloy with iron to produce hard stainless steel, in automobile accessories. Nichrome is used for resistance in electrical heating equipment etc. Chromite occurrences are very rare since large basic/ ultrabasic rock bodies (source rock) are not available in Nepal.

Titanium (Ti): Ilmenite ($FeTiO_3$) and Rutile (TiO_2) are the two chief ore minerals of Titanium. Minor amount of these elements mainly ilmenite are found in association with magnetite/ hematite ore at Thoshe (Ramechhap) and Bauligad (Bajhang). Tiny rutile and ilmenite grains along with zircon are commonly recorded in many heavy mineral concentrate samples from major rivers of Nepal indicating their source in higher crystalline rocks in the Higher Himalaya. Titanium is mainly used in paints and pigments, aircraft construction in both frames and engines. It is also used in alloys, electrodes in arc lights. Rutile is mostly used as a coating of welding rods.

Uranium (U) and Thorium (Th) both are radioactive elements. There exist 85 known uranium minerals in the earth however, in Nepal the ore of uranium like autunite ($Ca(UO_2)2(PO_4)_2.10H_2O$ are recorded in pegmatites from Thumki, Jagat, Panchmane, Gagalphedi and Chunikhel in Shivapuri area in Kathmandu. Other common uranium ores like uranitite (UO_2), pitchblende (U_3O_8), and few complex ores like torbernite, tyuyamunite, carnotite and cofinite are known from Upper Mustang, Tinbhangale, Chandi Khola and Chiruwa Khola (Makwanpur); Buka Khola (Sindhuli); Mardar Khola and Panpa Khola (Chitwan) *(Kaphle & Khan 1989, 1990, 2003);* Jamari Gad, Bangabagar, Baggoth and Gorang (Baitadi); and traces in different section of Chamliya River (Darchula). Preliminary investigation by DMG (*2014, 2016)* using Gamma Ray Spectrometer RS-125 and Scintillation counter was able to trace two radioactive beds at Lomanthang area in upper Mustang. Follow up investigations in eastern and western Lomanthang *(Khadka, 2019)* were able to trace noticeable size radioactive bodies. Among all the above mentioned areas Upper Mustang, Gorang and Tinbhangale prospects appear quite promising. Follow up detail investigation by DMG is warranted to confirm the reserve and grade. Th can replace U. Small amounts of Pb, Ra, Th, Y, N, He and Ar are also present in uranium ore. Pb/ U and He/ U ratios are used to determine the age of the rocks. Uranium is the source of radium and it emits Alpha, Beta and Gamma particles/ rays. U is mainly used as nuclear fuel in atomic power plants, nuclear arm and in medical diagnosis and treatments.

Bismuth (Bi): Bismuthinite (Bi_2S_3) is the chief ore of bismuth. In Nepal it is reported from Bamangaon polymetallic deposit in Dadeldhura *(Kaphle, 1997).* Baraghare and Mandu Khola area in Makwanpur districts. It is mainly used to make alloys with antimony, lead, tin and cadmium in medicine and cosmetic items.

Mercury (Hg) rarely occurs as native element. Cinnabar (HgS) is the chief ore of mercury. It is reported from Tirche Pani/ Taruka. Talalov (1972) has also reported cinnabar from the heavy concentrate samples from Khimti River and in zinc-lead ore from Pangu. It is used in amalgamation to liberate gold from other minerals/ metals, and in thermometers, barometers, and in many scientific equipment. It is a heavy and poisonous metal to human health.

Lithium (Li): Joshi (1984) reported the occurrences of lepidolite (lithium mic) from the pegmatites at Hyakule and Phakuwa (Sankhuwasabha). Lepidolite appears to be one of the source of lithium. Petalite (Li ($AlSi_4O_{10}$) and

spodumene ($LiAl(Si_2O_6)$ are the two main ores of lithium. It is mainly used in grease for lubricating properties, ceramics, batteries and welding flux etc. Now a days lithium batteries are common and also used in electric vehicles.

Beryllium (Be): Pegmatites are the store house of beryllium which can be extracted from beryl ($Be_3Al_2(Si_6O_{18})$ and aquamarine. Beryl are known from many pegmatite bodies in Manang (Naje), Kathmandu (Shivapuri), Nuwakot, Rasuwa, Sankhuwasabha (Phakuwa & Hyakule), Ilam, Taplejung and Bajhang (Khaptad) districts. Beryllium is a light metal as aluminum. It is generally used in alloy with copper to increase the hardness.

Arsenic (As): Arsenopyrite (FeAsS) and realgar (AsS) are the two main sources of arsenic, which occur mainly in polymetallic deposits like Bamangaon, Bering Khola and few other sulphide ore prospects. In many cases arsenopyrite is the pathfinder mineral for gold mineralization. It is used in some alloys with lead, and also used in medicine, insecticide, preservatives, pigment and in glass factories.

Tantalum (Ta) and Niobium (Nb): Tentalum and niobium are traced from the pegmatites and apical parts of tourmaline granites in the Lesser Himalaya. Chemical analysis of some of the muscovites from pegmatites of Phakuwa (Sankhuwasabha) has indicated up to 140ppm Ta *(Einfalt & Kaphle, 1995).* Tantalite $(Fe,Mn)Ta_2O_6$ is the main source of tantalum and niobium. Tantalum is also used to make filaments of electric lamp and rarely also employed in chemical equipment for surgery and tool steel in electric tubes. Niobium is used in alloys in weldable high speed steels, stainless steels in gas turbine of the aircraft industry.

Titanium (Ti): Sphene ($CaTiO(SiO_4)$ is the main source of titanium which has low density and high strength. It is durable metal for engineering applications and resistance to sea water. It is also used as in paint pigment. It is one of the common accessory mineral in granite, granodiorite, diorite, and nepheline syenite and generally associated with iron ores, zircon, and apatite.

Vanadium (V): Vanadinite ($Pb_5Cl(VO4)_3$ is the source of vanadium metal. Carnotite is also an ore of vanadium and uranium. Roscoelite is the vanadium mica. Talalov (1972) reported vanadium in tin and polymetallic ore at Melmura in Dadeldhura. Vanadium is chiefly used as a steel-hardening metal. Vanadium oxide is a mordant in dying.

Antimony (Sb) occurs in association with lead-bismuth ores at Barghare *(Talalov, 1972).* Stibnite (Sb_2S_3) is the chief ore of antimony which is used in various alloys as antimonial lead for storage batteries. Antimony sulphide is employed in the manufacture of fireworks, matches, pigments for making glass and also in some medicine.

Cadmium (Cd): Greenockite (CdS) is the source of cadmium and also occur in small amount with sphalerite like in Ganesh Himal Pb + Zn deposit. Cadmium is used in alloy for antifriction bearing low melting alloys, in pigments and chemicals. 1.5% Cd can harden copper and silver. The major use of cadmium is in electroplating other metals to form a coating resistant to chemicals. It is dangerous to health and can cause lung cancer and kidney dysfunction.

Rare Earth Elements (REEs) are set of 17 elements like Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tm, Tb, Dy, Ho, Er, Yb, Lu. They rarely exist in pure form rather they mix diffusely with other minerals. These elements are associated with alkaline rocks, granitic rocks, pegmatites, migmatized gneiss, carbonatite etc. Exploration of these very important elements has not been done in Nepal, however, possibilities of their finding is high in pegmatites, migmatized gneiss, nepheline syenite and granitic rocks of Nepal *(Kaphle, 2013, 1992).* REEs have multiple uses in modern electronic age in cell phones, laptops, aircrafts and hundreds of other sophisticated modern equipment.

All these above information indicate that Nepal is potential for metallic minerals. The exploration activities in the past have revealed that most of them appear to be economically worthwhile deposits. There are high chances to find some more prospects/ deposits in near future. Now the international price of many metals has gone up significantly, advance technology in mining, processing as well as the demand of most of metallic minerals is increasing day by day. Therefore, further detail investigations in the known areas, evaluation of specific prospects/ deposits and exploration in the new geologically prospective areas especially in the Higher Himalayan region might lead to find the potential economic metallic mineral deposits in Nepal. Exploitation of these minerals help to supply raw materials to the mineral based industry and reduce the import from other countries consequently save the foreign currency decrease in trade balance.

(B) Nonmetallic Minerals

A number of nonmetallic minerals like limestone, magnesite, phosphorite, talc, dolomite, quartz, mica, redclay, kaolin, silica sand, graphite, diatomite, gemstones, decorative and dimension stones and construction materials/ minerals are known from different parts of the country. Some of the important ones which are mined or explored up to certain stages are briefly described here.

B-1. Nonmetallic/ Industrial Minerals

Limestone: Over 1.3 billion metric tons of cement grade limestone deposits are already known from the Lesser Himalayan region only. Exploration of limestone by DMG, in the past was able to identify a number of large to small size limestone deposits. Based on the known cement grade limestone deposits, more than 27 cement industries are already in production, few others under construction phase and quite a few in the pipeline. Present domestic cement production could fulfill about 80% of the total internal demand. Few new cement industries will start their production soon. Therefore, establishment of more cement factories based on own limestone resources is still rewarding since the demand of cement in the country is ever increasing. Some of the main cement grade limestone deposits are Nigale (Dhankuta); Sindhali, Galtar, Chuladhunga and Gyampathumka (Udaypur); Bhainse, Okhare, Majuwa, Nibuwatar, Sukaura/ Budichaur (Makwanpur); Jogimara, & Beldada (Dhadhing); Kakaru Khola, Shikharpur (Sindhuli); Chovar (Kathmandu); Bhattedanda (Lalitpur); Lamatar, Balthali, Rosi, Nogure and Nandu (Kavre); Waling (Syangja); Jyamire, Koldanda, Masyam, Kerabari, Sisne/ Dobhan, Argali, (Palpa); Narapani and Supa Khola (Arghakhanchi; Gandari, Sewar Khola, Arung Khola, (Dang); Salendanda, & Neupane (Pyuthan); Kajeri, Sarada Khola, Kutichaur (Salyan); Bibang Khola and Rupla Khola (Rolpa); Chaukune and Lakharpata (Surkhet), Diyarigad, Bhumeshor, Chauraha, (Baitadi) and few other places in Lalitpur, Kavre, Khotag, Udayapur, Syangja, Palpa, Arghakhanchi, Dang, Pyuthan, Sallyan, Rolpa, Rukum, Bajura, Bajhang, Baitadi and Darchula districts. Preliminary studies indicate that there is a possibility to find more than 2.5 billion tons of cement grade limestone deposits only in the Lesser Himalayan region. The quality of limestone depends on its chemical composition like CaO%, MgO%, SiO_2%, Al_2O_3%, Fe_2O% LOI%. Based on chemical composition it is used to manufacture Portland cement, lime, agrilime, flux for iron and steel industries, agriculture, feed in poultry farm, leather industries etc. DMG issued 58 mining licenses and 178 prospecting licenses for limestone to private sectors. (DMG *Annual Report, 2019).* Annual production of limestone in 2018 was 6,621,614.96mt. *(DMG- CBS 2018).*

Dolomite ($CaMg(CO_3)$): In many cases dolomite and limestone beds/ bodies occur together in the same locality. From geological mapping it is known that over 5 billion tons (possible) of dolomite occur mainly in Mahabharat range in Dhankuta, Khotang, Udayapur, Sindhuli, Dolakha, Kavre, Kathmandu, Makwanpur, Dhadhing, Syangja, Palpa, Baglung, Gulmi, Arghakhanchi, Dang, Pyuthan, Sallyan, Rolpa, Rukum, Jajarkot, Surkhet, Dailekh, Jumla, Achham, Doti, Bajhang, Bajura, Baitadi and Darchula districts in the Lesser Himalaya and in some parts of Higher Himalaya and Tibetan Tethys (Inner Himalaya) region *(Kaphle,2005, 2020).* Most of them are not yet explored in detail and still do not know their grade and quality to utilize as raw materials for various industries. The quality of dolomite depends on its chemical composition like MgO%, CaO%, SiO_2%, Al_2O_3%, Fe_2O%, LOI%. Depending on these oxides it can be used in different industries. Dolomite is a potential source of metallic magnesium. It is used to manufacture soral cement and also in refractories, high magnesium lime, flux for iron and steel industries, ferroalloy industries, fertilizer industries and acid water treatment plants. Dolomite can be directly used in agricultural field to neutralize acidity and also to make up the loss of magnesia in soil. Chemicals like MgO, Mg(OH), $MgCO_3$, and $MgSO_4$ can be obtained from dolomite. $Mg(OH)_2$ is useful in preparing MgO and it is used as plastic filler for fire retarding properties and making refractory materials. $MgCO_3$ is used on a small scale as filler in the paper, paint, rubber, varnish and pharmaceutical industries. In huge amount it is used as building/ construction stone, aggregate for concrete, road fillings and asphalting materials. But unfortunately such huge resource of the country still remained unexploited in spites of its so many uses.

Phosphorite (Phosphate rock) is one of the main raw materials to manufacture chemical fertilizers like fused magnesium phosphate (FMP), triple super phosphate (TSP) etc. Present annual demand of chemical fertilizer in Nepal is about 300,000mt/year and its demand is increasing annually. Except three fertilizer blinding plant no other fertilizer industry based on the local phosphatrite + magnesium exist in the country. Phosphorite (0.7 - 0 4.7m thick bed) is confined to massive cherty and stromatolitic dolomite of Pre-Cambrian to Lower Paleozoic age that occur at Dhikgad, Junkuna, Morgaon, Sanagao, Rabana and Dhaubisaune areas in Baitadi, Far-western Nepal consists of 5 – 32 % P_2O_5 *(Bashyal, 1984).* Similar (1 to 23m thick) stromatolitic phosphorite band is also traced at Tarugad, Juilgad, Goichan - Kandechaur area in Bajhang and further east to Bajura *(Pradhanang 1983, Kaphle1997).* Dhakal

et al (2019), traced stromatolitic phosphorite from Juilgad, Bajhkada and Bhalene area in Bajhang. Detrital phosphorite fragments (<1mm - 1.5cm) are recorded from Eocene argillaceous limestone lenses and beds in Sewar Khola (Dang) and Mari Khola (Pyuthan) and P_2O_5 content in them is <5% to 10% *(Kaphle & Pradhanang, 1985)*. However, the phosphorite fragment itself revealed up to 25% P_2O_5. Exploration of phosphorite in the vicinity of MBT was able to trace few phosphate rocks consisting of <5% P_2O_5. Only few phosphate nodules/ lenses consist of up to 22% P_2O_5 in Takure, Barahakshetra, Tawa Khola *(Kazitsyn,1970);* Gawar Khola, Sewar Khola in Midwestern Nepal and in Khulia Khola *(Kaphle 1985 & 1997)* in Far-Western Nepal.

Magnesite ($MgCO_3$): 180 million tons (66 million tons of high grade, MgO content 88 to 96% loss free basis) of magnesite deposit in Kharidhunga, Dolakha; 20 million tons of medium to low-grade magnesite deposit in Kampughat in Udayapur district; and few small size magnesite occurrences from Palpa, Baitadi and Dolakha have been identified *(DMG,2004).* At Kharidhunga magnesite deposit an open cast mine has been developed to exploit magnesite as a raw material for Dead Burnt Magnesite (DBM) plant located in Lamosanghu, Sindhupalanchok district. Some technical problems appeared in ropeway to transport raw magnesite from mine site to plant site and also in test production of DBM. The mine as well as DBM plant is remaining unproductive since more than 18 years or so. Magnesite is a source of Magnesium. It is mainly used in the production of DBM from which high temperature furnace lining bricks are produced that can bear high temperature up to 2100°C in the furnace.

Talc ($Mg_3(Si_4O_{10})(OH)_2$: Occurrences of talc bands, lenses, veins and pockets are known in association with magnesite, dolomite and chloritic talc schist in different parts of Lalitpur, many places in Dolakha, Sindhupalchok, Dhadhing, Chitwan, Tanahun, Kaski, Syangja, Baglung, Surkhet, Bajhang, Bajura, Baitadi and Darchula districts. DMG did detail exploration only in Kharidhunga, where as in other places private companies and individuals are exploring and mining small scale talc mines. DMG has issued 18 prospecting and 14 mining license to the private sector *(DMG, 2018).* Kharidhunga talc mine is operating by Nepal Orind Magnesite since more than 2 decade. Its annual production is 8557.19mt in 2018.

Mica: Several but comparatively small occurrences of mica (mostly muscovite, biotite, and few lepidolite and phlogopite) books are known from different parts of Nepal. Mineable coarse size mica books are recorded only in complex pegmatites of Langtang (Rasuwa), Bhumidanda and Kharanetar (Nuwakot), Chaukibhanjyang (Kathmandu), Nibuwagaon (Sindhupalchok), Lekhpatan, Fulbari and Tikachaur (Jajarkot), Khaptad (Bajhang), Baskot, Balaita, and Bhasukan (Doti), Fikal (Ilam), Chilingdin (Panchthar), Rangmale, Akabu/ Sainsabu, Dobal Pokhari, and Khanigaon (Taplejung), Phakuwa and Hyakule (Sankhuwasabha) and at few places in Gorkha and Dhadhing districts. Only one prospecting license for mica was issued by DMG in 2018. Mica is chiefly used as nonconductor of heat and electrical insulating material in electrical equipment/ apparatus, fire proofing material. It is also used to manufacture of wall paper, lubricant when mixed with oils. Lepidolite is a source of lithium and also used to manufacture of heat resistance glass.

Ceramic Clay: Irregularly distributed scattered pockets of kaolin are known from Daman, Palung (Makwanpur), Panchmane (Kathmandu), Jitpurphedi, Dalchhap and few other places. Ceramic clay is derived from the deep weathering of pegmatite and granitic rocks. It is mainly used in the production of ceramic pots, utensils, tiles and other bathroom wears.

Laterite/ Red Clay deposits from Panchkhal (Kavre), Lamosure (Hetaunda), Trijuga/ Beltar (Udayapur), different parts of Nawalparasi, Chidika (Arghakhanchi), Guttu (Surkhet) are used in cement factories. Such red clay deposits are also known from different parts of Nuwakot, Dhadhing, Makwanpur, Nawalparasi, Udayapur, Palpa, Surkhet and few other districts *(Kaphle, 2019).* Clay from Thimi/ Bhaktpur is used in small-scale pottery industries. Huge amount of siltyclay deposits in different parts of Kathmandu valley is used to manufacture normal house bricks. In villages red clay and white clay (Kamero) are also used in house wall painting. Laterite are also used as substitute of iron ore in some cement industries. Aluminum rich laterite (bauxite) can be used to extract aluminium metal. DMG has issued 1 prospecting and 6 mining licenses to the public/ private sector in 2019.

Bauxite ($AlOH_3$) is an ore of aluminium metal**.** Aluminum has multiple use where light weight is desirable e.g. in aircraft, automobiles, railways, buses, cooking utensils, furniture, window/ door frame, electrical transmission lines, etc. Bauxite as such is not reported in Nepal. However, aluminous laterite containing <35% Al_2O_3 are quite common in different districts. Such aluminium laterite if upgraded by suitable beneficiation technique can be used for the extraction of aluminium metal *(Kaphle, 2019).*

Pyrite (FeS_2) is abundantly found in Bering Khola (Ilam), Chhirling Khola (Bhojpur), Dhusa (Dhadhing), Pandav Khani (Baglung), Meddi and Bamangaon (Dadeldhura), and many other places mainly in almost all polymetal sulphide deposits and copper sulphide deposits. It is mainly used to extract sulphur and manufacture sulphur compounds e.g. sulphuric acid, ferrus sulphate etc. Marcasite is also called white pyrite.

Silica Sand: DMG has proved about 11.9 million tons of silica sand suitable for glass industry in Karra Khola near Hetaunda, Makwanpur district. There is a possibility to find similar sand deposits in similar deposition environment (e.g. in Dudhaura Khola) and in other parts of Nepal. It is mainly used to manufacture glass, sandpaper etc.

Barites ($BaSO_4$) is also known as heavy spar because of its high specific gravity (4.5) among nonmetals. It occurs as gangue minerals in Ag, Pb, Cu, Co and Mn ores and also found in veins in limestone with calcite. Its occurrences/ prospects are known from Khanidanada (Pyuthan), Barghare (Makwanpur), Dokadhunge (Rolpa), Urathi, (Baitadi), and Phakuwa (Sankhuwasabha). So far exploration for barite has not been done properly in Nepal. Therefor true picture of barite resource is still unknown. It is the chief source of barium. More than 80% barite is used in oil and gas drilling and lithophone which is used in paint pigment industries and for barium meals in medical radiology.

Graphite (C) is one of the significant mineral in metamorphic terrain such as crystalline limestones, schists and gneisses in Lesser Himalayan regions. They are reported from Ilam, Dhankuta, Sankhuwasabha, Nuwakot, Sindhupalchok, Dhadhing, Baglung, Dadeldhura etc. It is mainly used in the manufacture of refractory crucibles for the steel, brass and bronze industries. It is also widely used in batteries, when mixed with oil as lubricant, and to manufacture lead of pencils. There is no existing proper graphite mine in Nepal.

Calcite ($CaCO_3$) deposits as such in large size are not known, however, minor calcite veins and lenses are recorded mainly in carbonate rocks. Calcite occurrences are known at few places as stalactite and stalagmite and incrustations as dog tooth spar in some of the limestone cavities/ caverns. One small scale calcite mine is under development stage in Nibuwagaon (Makwanpur). Calcite is mainly used in the production of cement, quick lime etc. Iceland spar is valuable and used in various optical instruments like Nicol prism to produce polarized light in microscope.

Diatomite is also known as diatomaceous earth. It occurs as fine grained deposit resembling chalk. Diatomite beds/ layers as much as 2m thick ar**e** reported from Chobhar, Thimi, Bode and few other places in Kathmandu valley. Small scale artesian mining of diatomite are in operation at Thimi and Bode in Bhaktapur district for local use. An overall assessment on quality and quantity of diatomite has not been done. Diatomaceous earth is used extensively as an abrasive, filler, and filtration powder and also in insulation products.

Rock salt/ Common Salt (NaCl): It is known as Halite. It is a common mineral precipitated from sea water and interstratified (incrustation) in sedimentary rocks mainly associated with gypsum, anhydrite, calcite and evaporite. Salt beds ranges from few cm to 10s of meters in thickness. Brine water/ salt springs that occur in Narsing Khola (Mustang), Chhiding Khola and Chharkabhot/ Dolpa *(Aryal, 1973)* are tapped and dried for common salt production. Brine water of these areas contains 1.5 to 3% NaCl, where as incrustation consist of up to 72.8% NaCl and 24.5% KCl. So far mineable salt deposit is not found in Nepal in spite of known brine water and incrustation of salt in Narsing Khola, Mustang. From geological study there is high possibility to find mineable salt deposits along with gypsum in Tibetan Tethys sedimentary beds in Manag, Mustang and Dolpa districts *(Kaphle, 2018).*

B-2 Precious and Semiprecious Stones (Gemstones)

Precious stones like diamond, ruby, sapphire and emerald are the chief valuable gemstones. In Nepal diamond is not recorded even in the Higher Himalayan region however, ruby and sapphire are known at few places.

Rubies and Sapphire: Both are transparent, clear, colored crystal of corundum**.** Gem quality but generally small crystals of light red to red ruby *(Fig.4A)* and light to dark blue colored sapphire are known from Chumar, Ruyil, Shelghar, Pola, Shongla in Ruby valley in Dhadhing *(Basset, 1984)* and Lari/ Ganesh Himal area in Rasuwa *(Kaphle, 2011)*. They occur in highly tectonized intensely folded en-echelon lenses of sacchoroidal dolomite (dolomitic marble) within the high-grade metamorphic rocks close to MCT. At places local people are illegally mining them haphazardly and destroying the precious resources of the country. They are used as gemstone in jewelry, crown etc. DMG must take strong action against illegal mining and manage it properly.
Emerald is deep green transparent beryl. It is very rare in Nepal. As other precious stone it is also used in jewelry.

Semiprecious stones like topaz, tourmaline, aquamarine/ beryl, garnet, kyanite, amazonite, amethyst, citrine, smoky quartz (quartz crystals) etc. exist mainly in Sakhuwasabha, Taplejung, Ilam, Manang, Bajhang, Nuwakot, Rasuwa, Kathmandu, Jajarkot, Achham and few other districts *(Kaphle, 2011).* They are briefly described below.

Tourmaline: Five distinct types of tourmaline are known from Nepal *(Basset 1978)*. Gem quality pink *(Fig.4B)*, and distinct multihued tourmaline (elbaite) of Hyakule and Phakuwa, pink, bright green, light orange sometimes with repeated color banding, olive green with amber colored core are known from Hyakule, Eastern Nepal *(Kaphle, 2011)*. Small-scale mines of aquamarine, beryl, tourmalines are in operation. Pegmatites of Langtang valley (Rasuwa), Naje (Manang), Daha and Garkhakot (Jajarkot), Ikabu and Lodantar (Taplejung) are also promising for tourmaline and beryl/ aquamarine. 12 prospecting license and 11 mining licenses for tourmaline are issued by DMG. Two tourmaline mines are in operation at Daha area in Jajarkot and six mines are in developing stage. Gem quality tourmaline are mainly used in jewelry.

Beryl/ Aquamarine of Taplejung (Ikabu, Lodantar *(Fig.4C)* area are high priced. In Taplejung 2 beryl and aquamarine mines are in operation whereas the tourmaline mines are still in development stage. Topaz and Emerald are rarely found in Nepal. Gem quality clear blue aquamarine of Phakuwa (Sakhuwasabha), aquamarine/ beryl and few green colored tourmalines from Naje and few other localities in Manang district *(Tamrakar, 1990, and Einfalt and Kaphle, 1995),* western Nepal are well known. Lekhpatan and Tikachaur in Jajarkot; Jagat, Panchmane, Kagtigaon in Kathmandu; Baguwa, Tarkeghyang, Nibuwagaon in Sindhupalchok are the other known localities for beryl. They were mined from Phakuwa, Hyakule, Naje, Yemphudin and Khaptad till few years before. Emerald and Aquamarine are used in jewelry, ornaments, and all other low quality beryl used to extract beryllium.

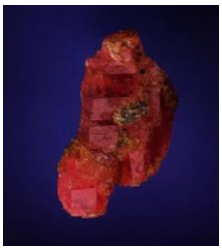


Fig.4A: Ruby from Dhadhing

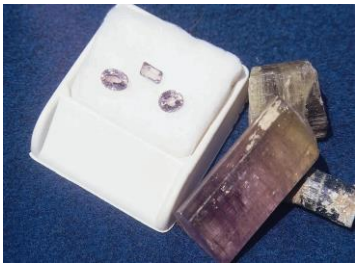


Fig.4B: Pink Tourmalin from Hyakule

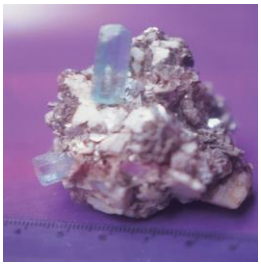


Fig.4C: Aquamarine from Taplejung

Garnets are recorded from strongly tectonized lenses and pods of chlorite-biotite-garnet schist within high-grade metamorphic rock sequence mainly in the Higher Himalayan region. Deep red or red colored almandine, hessonite and pyrope garnet are mined mainly in Sankhuwasabha, Taplejung, Sindhupalchok Dolakha, and Rasuwa districts. Small-scale garnet mines were in operation at Budhekhani, Bhote Khola, Hanglaung, Khining, Sunamla, and Swachi Khani in Sankhuwasabha district *(Kaphle, 2011)* but closed since last few years due to difficulty in mining at depth and lack of proper mining technique. Three prospecting licenses were issued by DMG before but at present none.. Colorful garnets are used as gemstone and others are used in abrasive powder etc. It is an inexpensive gemstone

Amazonite/ Amazon stone is a light green colored microcline feldspar. It is found in the pegmatites at Hyakule, and Phakuwa in Sankhuwasabha, Naje in Manang and some parts of Taplejung. It generally occurs together with tourmaline and quartz crystals in pegmatite. It can be mined at the same time with tourmaline.

Epidote: Elongated crystal of pistachio-green to yellowish green colored transparent crystals of epidote are known from epidote garnet schist and gneiss in Manang district. It is not common as garnet, tourmaline etc.

Quartz Crystals (SiO_2) are also known as rock crystal**.** They are known from different parts of Jajarkot, Dailekh, Dhadhing, Rasuwa, Nuwakot, Sakhuwasabha, Ilam and Taplejung districts *(2008, 2011).* 4 Mining license and 3 prospecting licenses for quartz are issued by DMG (2018). 2 small-scale quartz crystals mines are in operation from pegmatites at Khejemi/ Sirku in Taplejung, *(Fig.5B)* and at Raluka in Nuwakot. Quartz has many uses. Only colored verities like amethyst, rose quartz, citrine and smoky quartz are cut for gems. However, Agate, Cat's eye, bloodstone and jasper are also used as gem stones. Rock crystals are mainly used for decoration as well as an abrasive, manufacture glass and silica bricks. In powder form it is used in porcelain, paints, sandpaper, scouring soap. Perfect, transparent quartz crystals are used as prism and lenses in optical and scientific apparatus like microscope and

telescope. Because of piezoelectric properties it is also used in radio oscillators to permit both transmission and reception on a fixed frequency and as battery in quartz watch etc.

Kyanite (Al_2SiO_5) occurrences/ prospects are known mainly from high grade metamorphic rocks like Kyanite schist in Dolakha, Sankhuwasabha, Taplejung, Rasuwa, Dhadhing, Jajarkot and Achham districts. Four small-scale kyanite mines are in operation in Daha and Suneri in Jajarkot and Barah of Aachham districts *(Kaphle, 2011)*. 9 prospecting licenses and 8 mining licenses are issued by DMG (2018) but only 4 of them are in operation and 4 others in development stage. Elongated tabular inky blue/ sapphire blue kyanite crystals are cut for gems *(Fig.5A).* Most of the raw kyanite from Achham and Jajarkot are send to India for cutting and polishing. Kyanite is also an inexpensive gemstone like garnet. But still it is used as gemstone and in spark plugs.

Fig.5A: Kyanite (raw & cut polished) from Jajarkot

Fig.5B: Quartz Crystal from Taplejung

B-3 Decorative and Dimension Stones

Marble: Pink, gray and white colored marble deposit (1.63 million ton) is located in Godavari, Lalitpur district. Based on this deposit Godavari marble industries (Pvt.) Ltd. is established. Its annual production capacity is about 80,000m^2 polished marble slabs. It was producing annually about 50,000m^2 to 70,000m^2 polished marble slabs and some crazy marble, chips and aggregate as bi-products *(Kaphle & Jnawali,1994)* but since last 10 years the mine is shut down due to some environmental and legal reason. Based on Anekot (Kavre) marble deposit Everest marble and allied industry is in operation. Recently Nawadurga Marble Industry Pvt. Ltd has also developed marble quarry at Chhatre Deurali in Dhadhing and started its production. 1 prospecting and 3 mining license are issued by DMG (2018) and two of them are in production. In total only 888sq.meter marble was produced in 2018.

Granites of Cambrian to Ordovician age are known from Makwanpur (Palung, Ipa and Narayanthan), Sindhuli, Udaypur, and Dadeldhura in the Lesser Himalaya *(Kaphle1992)*. Late phase tourmaline granites (Miocene) are also known from the Higher Himalayan and Inner Himalayan (Tethys) regions. Coarse grained, massive granites are used as decorative and dimension stones. Granite slabs are also used in dining table, and external flooring and decoration. 3 prospecting licenses are issued by DMG (2018) but not a single granite quarry is in production.

Quartzite is a hard metamorphic rock which consists of mainly quartz. It is abundantly known from many places in Taplejung, Ilam, Panchthar, Solukhumbu, Dhankuta, Ramechhap, Sindhupalchok, Kavre, Makwanpur, Dhadhing, Nuwakot, Tanahun, Kaski, Syangja, Parbat, Baglung, Myagdi, Dang, Sallyan, Rolpa, Rukum, Jajarkot, Achham, Doti, Bajhang, Bajura, Dadeldhura, Baitadi, Darchula and few other districts. It is mainly used as dimension stone and flaggy cericitic quartzite as slabstone for roofing, flooring and wall decoration. DMG has issued 12 mining and 50 prospecting licenses in 2018. Its demand is fairly high in Kathmandu, Pokhara and other cities.

Slate is the common roofing and pavement material (rock) that is extensively mined locally in different parts of Taplejung, Dhankuta, Sindhupalchok, Ramechhap, Nuwakot, Sindhupalchok, Dhadhing, Gorkha, Myagdi, Baglung, Parbat, Jajarkot, Achham, Doti, Dadeldhura, Baitadi, Bajhang, Bajura and many other districts since historic time and used widely. No license is required from DMG to mine slate in very small scale for household use. However, local government may take some royalties from such mining.

B-4 Construction Minerals (Materials)

Rocks are the main construction materials since the Stone Age. Some of the rocks like marble, basalt, granite and sandstones are cut into slabs and used in decoration; phyllite, slates, flaggy quartzite and schist are used for roofing; limestone, dolomite, quartzite, sandstone are used for aggregate in various construction works, road paving and flooring. Vast quantities of river boulders, cobbles, pebbles and sands are mined as construction materials/ aggregates. DMG *(Sharma et al 1988)* has evaluated such materials (boulders = 347,006,000m3, cobbles = 214,261,000m3 and pebble = 229,205,000m3) in the major rivers in Terai region. Now this record changed significantly due to extensive mining of such materials haphazardly from most of the rivers.

(C) Fuel Minerals

Coal: In Nepal low to medium grade coal seam occurrences/ deposits are known in four stratigraphic positions like (a) Quaternary peat/ lignite (b) Siwalik coal (c) Eocene Coal and (d) Gondwana coal. Peat/ lignite in Kathmandu valley is mined and used mainly in brick burning along with fire wood. Sporadic small coal seams in Siwalik is not economically attractive because of scattered small occurrences. Eocene coal occur as irregular seams confined to orthoquartzite at Tosh, Siuja, Azimara and Abidhara in Dang, and few places in Sallyan, Rolpa, Pyuthan and Palpa districts. Small scale 11 coal mines are in operation in these districts. In addition to that 4 prospecting license are also issued by DMG. Present coal production in Nepal is insignificant, about 11,522mt in 2018 *(DMG/ CBS, 2018).*

Petroleum and Natural Gas: A number of oil and natural gas seeps are recorded in a stretch of about 14km in Padukasthan, Sirsethan and Navisthan area in Dailekh *(Fig.6A)* and only gas seeps at Muktinath in Mustang. GON/DMG/ PEPP have given high priority to explore and promote petroleum exploration in Nepal since 1982. DMG/ PEPP were able to identify 10 prospective blocks in the southern parts of the country *(Fig.6B).* Shell/ Triton Company, conducted exploration in Block no.10 (Biratnagar block) in eastern Nepal. It has conducted Seismic and gravity survey and also drilled a test well up to a depth of 3520m, but the hole appeared dry. Later on Texana Resources Company of USA in 1998 and Cairn Energy PLC of UK in 2004 have initiated the petroleum exploration works in Block no 3 & 5; and Block 1, 2, 4, 6 & 7 respectively. The possibility of finding oil in some of these blocks appears fairly high but these companies were reluctant to conduct extensive exploration works in the field. GON cancelled the agreement and both companies left Nepal in 2013. Recently (since 2019) GON/DMG in technical cooperation with Chinese Government has started petroleum exploration and detail investigations in Padukasthan, Navisthan, Sirsasthan and surrounding area where oil and gas seepages are seen since long time, in Dailekh district. The field working team has completed seismic survey 400sq.km area and collected some rock, soil, and gas samples and sent them to China for further laboratory investigation and seismic data interpretation.

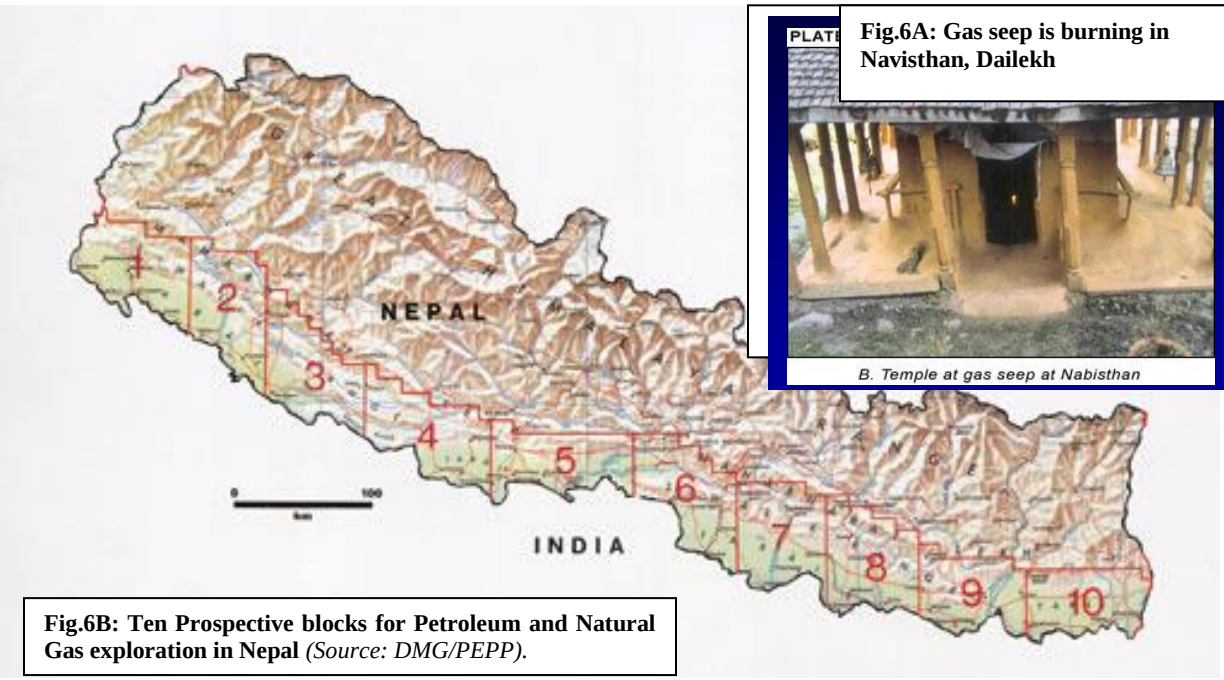


Fig.6A: Gas seep is burning in Navisthan, Dailekh

Fig.6B: Ten Prospective blocks for Petroleum and Natural Gas exploration in Nepal *(Source: DMG/PEPP).*

Methane gas deposit in Kathmandu Valley is known since long time. It dissolves in water type biogenic gas. DMG explored this gas in 26 sq. km area in Kathmandu valley by exploration drilling of over 15 drill holes up to 570m depth and proved 310 million cubic meter methane gas deposit. The gas occurs at different depth from 120m to 300m. Its average calorific value is 7200kcal/m^3. A model gas plant is set at Tripureshor/ Teku. Feasibility study has confirmed that the gas can be used for industrial and household purpose and the reserve is sufficient to supply gas to 21,000 families for about 30 years. The GON/ DMG is inviting for potential investor to come forward with suitable proposal to develop the gas wells and commercialize this gas deposit for the benefit of the people.

Geothermal Hot Springs: During preliminary study 29 geothermal hot springs are identified and few more are also reported in different parts of the country. Mostly they are found to be associated with Main Central Thrust and confined to the banks of Mahakali, Karnali, Tila, Kaligandaki, Myagdi, Marshyangdi, Trishuli, and Bhotekoshi Rivers and in Kodari. The temperature of the hot spring water ranges from 40° to >60°C *(Costa et al, 2014)*. It can be utilized for heating, drying fruits etc. In Sindhupalchok at Kodari and Myagdi at Tatopani and Mygdi Khola hot springs foreign tourists and local people take hot water bath to heal skin disease and pain due to arthritis etc.

Radioactive Minerals like uranium are known from Sindhuli, Makwanpur, Chitwan, Kathmandu, Baitadi and Mustang districts *(Kaphle & Khan, 1989, 1990, 2003).* There is a high possibility to find such minerals in the granitic terrain (granite, gneiss and pegmatite) in the Tethys, Higher and Lesser Himalayan regions and from the upper Middle Siwalik sandstone. Prospection of radioactive minerals by DMG in Mustang district *(Khadka, 2019)* was able to trace some prospective radioactive bodies in upper Mustang. Follow-up exploration was able to delineate such high radioactive bodies in upper Mustang, Tinbhangale, and Gorang. The grade and tonnage of these prospects have not yet confirmed by exploration drilling. Uranium is a major source of nuclear fuel for the production of Nuclear energy. It is also used in nuclear arms and ammunitions, age dating of rocks and also in X-Ray, C-T Scan for diagnosis and treatment of cancer in medicine.

Contribution from Minerals and Mines

As per DMG record it is known that it has issued about 365 and 388 prospecting licenses and about 121 and 142 mining licenses in FY 2074/075BS and 2075/076BS respectively. In the last two fiscal years DMG has also collected Rs1,139,396,240/ and Rs770,323,724/ respectively as royalti**es,** various type of taxes, fees, surface rental of lease area etc. *(source DMG, Planning section)***.** In addition to that local governments (previously District Development Committees) collect about Rs1,000,000,000/ per year as local taxes and fees from river boulders,/ gravel/ sand quarries operated in their respective territories. For detail about the annual production of different minerals and royalty collected by DMG refer its website: *www.dmgnepal.gov.np* or contact the Planning section.

Mineral resources and petroleum reserve can play vital role in the industrial development, create job opportunities for many unemployed people, help to reduce import and subsequently to minimize trade deficit, elevate poverty line and overall contribution in the national GDP. At present minerals and mine contribute only about 0.6% and mineral industries sector contribute just around 2.5% to national GDP, which is not encouraging at all. It is envisaged that if the GON give high priority to focus to exploit mineral resources, develop all necessary infrastructures to access the deposits, follow liberal policy and provide incentives like tax holidays for first 3 – 5 years, and encourage them by providing laboratory and technical support/ advice to the investors, geoscientists are pretty confident that within next few years more industrial minerals, base metals, precious metals, gemstones, and petroleum will be well explored and proved and a number existing raw minerals will be utilized, more mines will come in operation/ production and more mineral based industries and petroleum industries will be established in Nepal. In such case this sector could contribute 15 – 20 % in national GDP. However, mining activities should be carried out with minimal damage of natural environment by applying appropriate technology and immediate rehabilitation of the mined land.

Investment Opportunity in Mineral and Mining Sectors

There are ample opportunities for the interested national and international investors to invest in the commercially viable mineral commodities and petroleum exploration that deserve investment. Some of the existing economic mineral deposits have been developed and are being used in industries like cement, industrial lime, agriculture lime, dead burnt magnesite, talcum powder, and marble industries. Some small-scale industries are using local limestone, dolomite, quartz, talc, clay, coal, peat, precious and semiprecious stones, brine water (salt) etc. There is a high demand of gold, iron, copper, zinc, REEs, rare metals, gypsum, phosphorite, gemstones, coal, petroleum and natural gas, construction materials such as aggregate, dimension/ decorative stones, paving stones, slates, boulders, gravel and sand. Investment in these potential mineral resources especially iron, gypsum, precious stones and precious metals, base metals is highly rewarding at present. Petroleum exploration also provides promise for investment in Nepal. International oil companies are welcome to invest in petroleum sector. Government of Nepal amended the existing Mines and Mineral Act and Regulations as well as Petroleum Act and Regulations and offer conducive policy environment and committed to provide essential services like infrastructures and other related facilities, concession in tax system, soft loan from banks and also establish provincial offices to provide fast services to the people from all the seven provinces. All these provides ample opportunities to invest in commercially viable mineral resources as well as in petroleum exploration industrial development in Nepal.

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