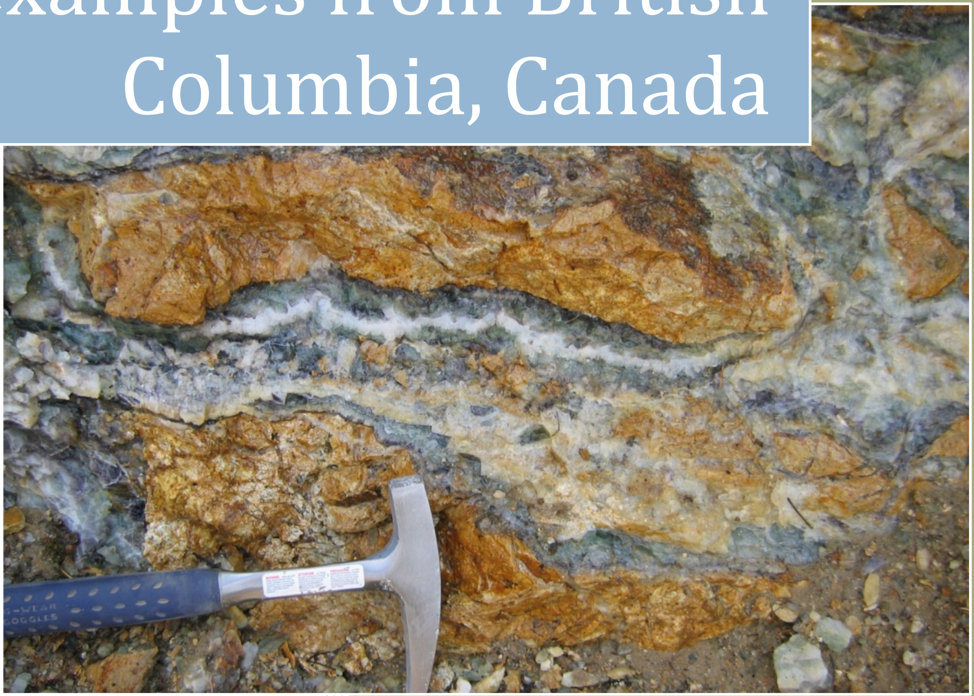
Information Circular 2009-4

World fluorspar resources, market and deposit examples from British Columbia, Canada



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Ministry of Energy, Mines and
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Suggested reference

Simandl, G.J. (2009): World Fluorspar Resources, Market and deposit examples from British Columbia, Canada; *British Columbia Geological Survey*, Information Circular 2009-4, 16 pages.

Cover Photo

Coarse fluorite (pale to dark green and purple) cementing a breccia and replacing fragments of the host rock. Quartz is white. Rock Candy mine, southern British Columbia, Canada.

World fluorspar resources, market and deposit examples from British Columbia, Canada*

By George J Simandl[1,2], P.Geo., Ph.D.

Executive Summary

Key questions addressed in this paper are: “Will the demand for fluorspar outstrip supply in the foreseeable future?” and “Will there be enough raw materials to cover projected demand?” The demand for fluorspar is linked to global economic cycles. Superimposed on economic cycle-related fluorspar trends are more discrete variations caused by commercialization of technological innovations, rapid changes in environmental regulations and government-imposed trade restrictions. Regional conflicts or political upheavals in major fluorite-producing countries may have a major impact on fluorite markets, but such events are difficult to predict.

This paper concentrates on the global availability of fluorspar from the perspective of geological and mineral engineering economics. Fluorspar reserves and reserves base, as estimated by Miller (2008a), are sufficient to meet the world’s short-, medium- and long-term acid-grade fluorspar requirements. However, if reserve and reserve base estimates for China are correct, we can expect a major shift in fluorspar production from China to other countries with substantial known reserves but little or no fluorspar production. There is less information regarding raw materials for production of metallurgical grade fluorite. Long-term relations between fluorite demand, production, reserves and fluorite reserve base are elastic and constantly adjusting. As the demand for fluorspar increases, so does its price and some deposits previously deemed uneconomic or sub-economic become mines.

In the short term, there may be shortages in specific fluorspar products because in developed countries, it takes several years to bring a new mine into production; however, there are many existing fluorspar producers that would be thrilled to take advantage of recent fluorite prices and expand their share of the market. Any shortages are likely to be short-lived. Unexpected governmental interventions, technological breakthroughs requiring high-volumes of fluorite, or international conflict and political upheavals involving major fluorspar-producing countries may seriously affect the short- or medium-term balance between fluorite demand and supply.

Recently, high fluorspar prices and overall fluorspar demand made it possible to raise capital to restart mines that were forced to shut down due to low fluorspar prices in early 1990’s and to finance development of new fluorspar deposits. World-scale economic slowdown may result in decreased demand for fluorspar and cause corresponding price adjustments but it is highly unlikely that fluorspar production will go down to 1994 levels (3.75 million tonnes/year) unless the economic recession turns out to be more prolonged than expected. British Columbia has several fluorite-bearing deposits, discussed in this paper.

This paper was originally presented at the Fluorspar 08 Conference, Organized by *Industrial Minerals* and held in Montreal, Canada on October 15-17, 2008.

Introduction

Fluorspar, the commercial term for fluorite (CaF_2) is the principal industrial source of the element fluorine (F). Fluorite has a vitreous lustre, a perfect octahedral cleavage and a hardness of 4. The density of transparent fluorspar is typically 3.18 g/cm^3, depending on the abundance of fluid and solid inclusions, fluorite density may vary from 3.0 to 3.6 g/cm^3. Fluorite has a melting point of 1418°C. Fluorite comes in a variety of colors: colorless, white, yellow, blue, green, rose, red, brown or nearly black, but the purple variety is most common. Ideally, fluorite contains 51.1% calcium and 48.9% fluorine. Small quantities of rare earth elements (REE), strontium and other elements may substitute for calcium within the fluorspar crystal structure. Collector specimens occur as well-formed cubes and octahedrons. Typical fluorspar ores are massive or form layered crusts, globular and botroidal

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*Paper originally presented at the Fluorspar 08 Conference, October 15-17, 2008, Montreal, Canada, organized by *Industrial Minerals.*

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aggregates or cox-comb textures. Fluorite may also show a variety of replacement textures, fill hairline fractures, exist as disseminations within the host rock or be intergrown with variety of gangue minerals.

Other potential commercial sources of F are cryolite and phosphate rock. Cryolite (Na_3AlF_6), an uncommon mineral, was produced in the past in Greenland. Its use has since been replaced by synthetic cryolite. Market conditions permitting, due largely to increasing environmental pressures on fertilizer producers, fluorine compounds could be also extracted from sedimentary phosphate rocks that contain typically 3 to 4% fluorine (Steininger,1972; Laghzizil et al., 2000; Kauwenberg and McClellan, 2004; Miller, 2008a). Fluosilic acid (H_2SiF_6) is one of these compounds. It was traditionally neutralized with lime and then disposed of. Lately it has been used extensively in water fluoridation. Recent changes in environmental regulations are suggesting that this acid will be increasingly converted into aluminum or calcium fluorides, cryolite, or hydrofluoric acid (Dreveton, 2000). Phosphate rock reserves in the USA alone are estimated to contain 370 million tonnes of fluorine (Word et al., 1973; Grogan and Montgomery, 1975; Fulton III and Miller, 2006). Topaz ($Al_2SiO_4(F,OH)_2$), villaurmite (NaF), sellaite (MgF_2) and bastnasite ($(Ce,La)CO_3F$) are some of the well-known F-bearing minerals; however, they are not currently considered as commercial sources of fluorine.

Fluorspar Production and Prices (1900 to 2008)

The US Geological Survey first reported world fluorspar production at 171 000 tonnes (Figure 1). Fluorspar production first exceeded 1 million tonnes/year during World War II. It peaked at 5.56 million tonnes/year in 1989 and then bottomed out at 3.75 million tonnes/year in 1994. The market stabilized in the 4.2 - 4.5 million tonne/year range between 1997 and 2000. By 2004 fluorspar production consistently equalled or exceeded 5 million tonnes/year (US Geological Survey, 2007). The rapid decrease in fluorspar production that preceded the market low of 1994 was largely due to restrictions on the use of fluorocarbons (particularly CFCs) in refrigerant gases, aerosol propellants and foam blowing agents related to the Montreal Protocol.

The variation in price of fluorspar in the USA over the last 100 years is shown on Figure 2. The combination of low demand and low price linked to high volume of competitively priced Chinese exports resulted in closure of many fluorspar mines, particularly in North America and Europe. Anti-dumping duties against Chinese acid-grade fluorspar exports were followed in the late 1990's by the introduction of export quotas and tariffs by the Chinese government that increased prices of fluorspar concentrate. By 2005 fluorspar prices reached US$235/tonne, in US ports (Roskill 2005) and the average value of imported fluorspar to the United States was over US$200/tonne (US Geological Survey, 2007).

Figure 1. World fluorspar production from 1913 to 2007. (Based on the compilation produced by the US Geological Survey, 2007).

Reductions of fluorspar concentrate exports from China, in combination with a relatively steady market and anticipated modest market growth, resulted in price strengthening and encouragement of fluorspar production outside of China. There are several proposals for start-up of new mines or reactivation of closed ones (Chegwidden and Huxtable, 2008). World fluorspar production has exceeded 5 million tonnes/year since 2004 (Figure 2). Acid-grade may account for 70% of it (Roskill, 2005). Only time will tell if the production of 2010 and 2011 will hold above the 5 million tonnes level.

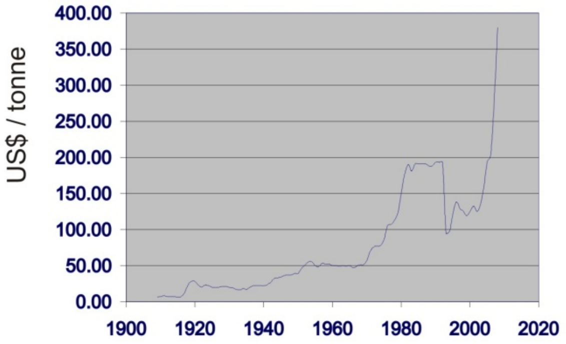

Figure 2. Variation in fluorspar prices between 1917 and 2008, not corrected for inflation. (Based on the compilation produced by the US Geological Survey, 2007).

Fluorspar Use

Worldwide, the chemical industry is the largest user of fluorspar. Fluorspar is used in the manufacturing of fluorocarbons, mainly for refrigerants and foam products, and in production of polytetrafluoroethylene (PTFE), commonly known as "Teflon" (Trademark of DuPont) and other fluoropolymers. Petroleum alkylation (a major step in petroleum upgrading), glass, medical, agricultural and metallurgical uses also represent important markets. Demand for fluorspar in the manufacture of fluoropolymers and fluoroelastomers, including partially fluorinated polymers or copolymers that are more stable chemically and thermally than other elastomers, is growing rapidly (Roskill, 2005; Miller, 2008b). There are substantial differences in end uses of fluorspar in North America, Japan and Europe; however, there is a sharp contrast in the use of fluorspar between developed and developing countries (Crossley, 2004). Over 70% of fluorspar used in developed countries is transformed into HF products, while in developing countries over 65% of fluorite is used in steel-making. Fluorspar uses in the USA are summarized on Figure 3.

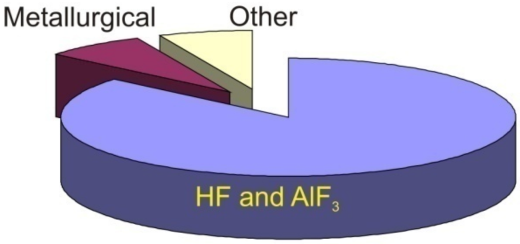

Figure 3. Fluorspar uses in the USA. Data used to construct this diagram comes from Miller (2008b).

Aluminium manufacture also represents an important segment of the fluorspar market. Aluminum fluoride (AlF_3) and synthetic cryolite, derived largely from acid grade fluorspar, are the main fluorine compounds used in aluminum smelting. The growth of this market is favoured by increasing demand for aluminium in the automotive industry, but it is counterbalanced by improvements in smelting technology, increased recycling of both, aluminium and fluorine, and by increased use of AlF_3 derived from fluosilic acid (Roskill, 2005; Chewigen and Huxtable, 2008).

Metallurgical and some acid grade fluorspar products are sold to steel mills, cement plants, foundries, glass and ceramic plants, and welding rod manufacturers where they are used as fluxes (Grogan and Montgomery, 1975; Miller, 2008a, b).

Major Fluorspar-producing Countries

According to Miller (2008b), in 2007 world fluorspar production was approximately 5.59 million tonnes. China, at 3.2 million tonnes, is the largest fluorspar producing country (Figure 4) and is in the position to control or at least strongly influence fluorspar prices. It is followed by Mexico (933 000 tonnes), Mongolia (380 000 tonnes), South Africa (285 000 tonnes), Russia (180 000 tonnes), Spain (155 500 tonnes), Namibia (118 000 tonnes) and Morocco (95 000 tonnes). For most producing countries it is possible to establish the proportions of acid grade and metallurgical grade concentrates, but for some this distinction can't be achieved. A large proportion of the Mongolian "metallurgical grade" may be lower grade products used by the cement industry.

Recently, due to increased internal demand, China has been diverting an increased proportion of its fluorspar output to domestic production of HF and thus its fluorspar exports are shrinking. Also, export tariffs and quotas have been introduced to limit fluorspar exports. Prices of fluorspar concentrates have risen in terms of US dollars (Figure 2), creating opportunities for fluorspar producers outside of China to expand operations or reactivate mines that shut down due to low fluorspar prices during the 1990's. New fluorspar deposits are now being promoted. Since the summer of 2007, economic growth in China slowed down from 13% to 8% (more than expected). It remains to be seen if China will maintain its present export restrictions on fluorspar, reduce them, or replace them with export rebates.

Fluorspar Geology

Fluorite is present in a wide variety of geological settings (Grogan and Montgomery, 1975; Harben, 1999; Fulton III and Miller, 2006). Unfortunately, in many cases the lack of bedrock exposure and laboratory work prevents scientists and engineers from determining the origin of fluorite in many deposits. In classical cases, regardless of the deposit origin, fluorite is the main (or the only) economically recoverable ore constituent. This is illustrated by the following deposits: Las Cuevas, Encantada-Buenavista, El Triangulo (Mexico); St. Lawrence pluton-related veins and the Rock Candy Mine (Canada); El Hamman veins (Morocco) and Le Burc,

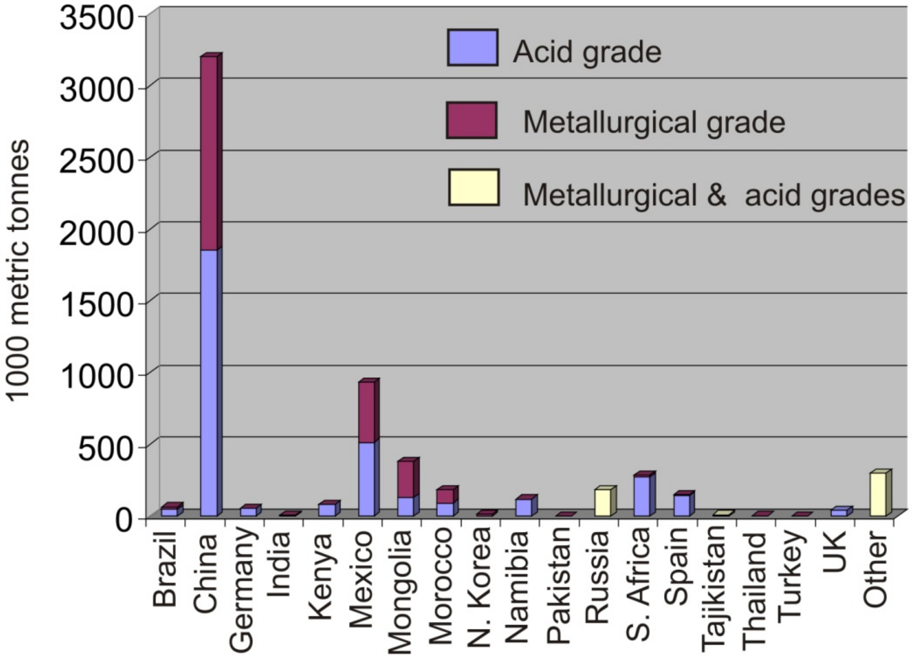

Figure 4. World metallurgical and acid grade fluorspar production by country for the year 2007. Data from Miller (2008b).

Montroc–Le Moulinal and Trebas deposits (France) as documented by Ruiz et al. (1980), Grogan and Montgomery (1975), González-Partida et al. (2003), Munoz et al. (2005), and Fulton III and Miller (2006). Most recent research highlights metallogenic associations of fluorite with more exotic industrial minerals or metals.

Fluorite mineralization is commonly associated with or is a part of carbonatites and alkaline complexes, Mississippi Valley-type Pb-Zn-F-Ba deposits, F-Ba-(Pb-Zn) veins, hydrothermal Fe (± Au, ±Cu) and REE deposits, precious metal concentrations, fluorite/metal-bearing skarns, Sn-polymetallic greissen-type deposits, zeolitic rocks and uranium deposits (Grigan and Bradbury, 1967 and 1968; Baxter et al., 1973; Sheppard and Mumpton, 1984; Kesler et al., 1989; Cunningham et al., 1998; Andrade et al.,1999; Hagni,1999; Fourie, 2000; Hill et al., 2000; Cardellach et al., 2002; Liu et al., 2003; Alvin et al., 2004; Goff et al., 2004; Xu et al., 2004; Bettencourt et al., 2005; Min et al., 2005; Levresse et al., 2006; Salvi and Williams-Jones, 2006). Consequently, the number of proposed development projects where fluorite is considered as a potential co-product of metal extraction is on the rise. At first glance the co-production of fluorite with metals appears an attractive proposition but in many cases such association represents increased capital and processing costs. The understanding of the geology of fluorite- and metal/fluorite-bearing deposits is important to design efficient exploration programs not only for fluorite but for related metals and also for the mineral potential assessments of large territories.

Regardless of the origin of fluorite, from the mining engineer's and metallurgist's points of view, economic fluorite deposits occur as simple or composite veins, stockworks and breccia zones (Figures 5 and 6), diatreme pipes, disseminations (Figure 7) or other features where fluorite occurs as open space fillings such as in karst. Replacement-type, residual (unconformity-related) and stratiform bodies are also economically important and are known to form some high-grade deposits (Baxter et al., 1973, Grogan and Montgomery, 1975, Fulton III and Miller, 2006). Vein-type deposits are the most common and historically have supplied the majority of the fluorspar market.

Grade and tonnage curves can be constructed for most fluorite deposit types and Figures 8 and 9 represent those for vein-type deposits. Cumulative curves like these were originally produced for mineral potential assessments (Orris,1992) but they can be used for conceptual studies and during the early screening of exploration and development projects. The vertical axis of these diagrams is divided from zero to one. The horizontal axis represents either tonnage (in metric tonnes) or grade (% CaF_2). For example, from Figure 8 we can determine that 90% (0.9 on the vertical scale) of fluorite vein-type deposits have grades (fluorite content) higher than 23% CaF_2. Half (0.5 on the vertical scale) of these deposits have fluorite content

Figure 5. Coarse fluorite (pale to dark green and purple) cementing a breccia and replacing fragments of the host rock. Quartz is white. Rock Candy mine, southern British Columbia, Canada.

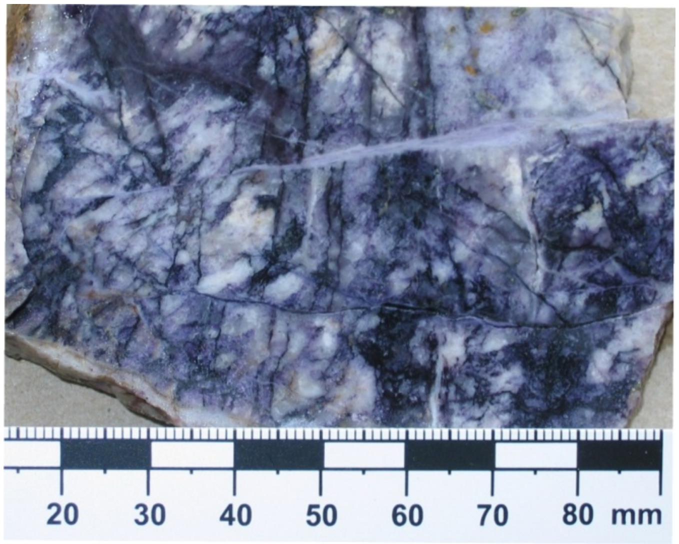

Figure 6. Crackle breccia. Dark purple, fine-grained fluorite fills fractures and replaces the pale gray limestone. Rock Canyon Creek deposit, southeastern British Columbia, Canada.

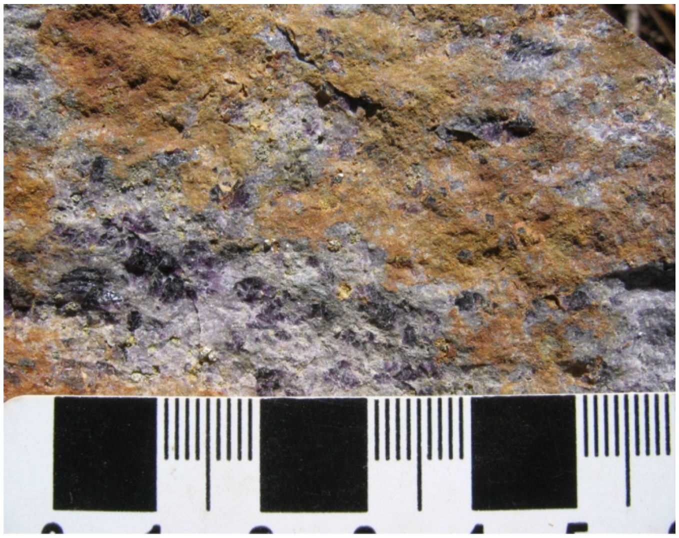

Figure 7. Fluorite disseminated in trachytic meta-tuff, Rexspar deposit, central British Columbia, Canada. Fluorite is purple to almost black. Weathered sulphides give the rock a rusty-brown appearance (fine division on the scale = 1mm).

higher than 44% CaF_2, and less than 10% (0.1 on the vertical scale) of the deposits have a grade higher than 64% CaF_2. The same approach is used to interpret Figure 9. Deposits with above average grade and tonnage are preferred targets for more detailed investigations. There is also higher probability that such deposits will remain economic during times of recession (low fluorspar prices).

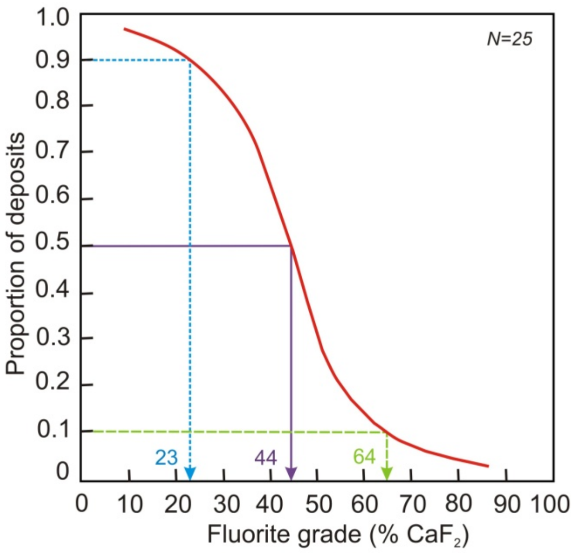

Figure 8. Fluorite vein grade model can be used in mineral potential evaluations and in early screening of fluorite development projects. From Orris (1992).

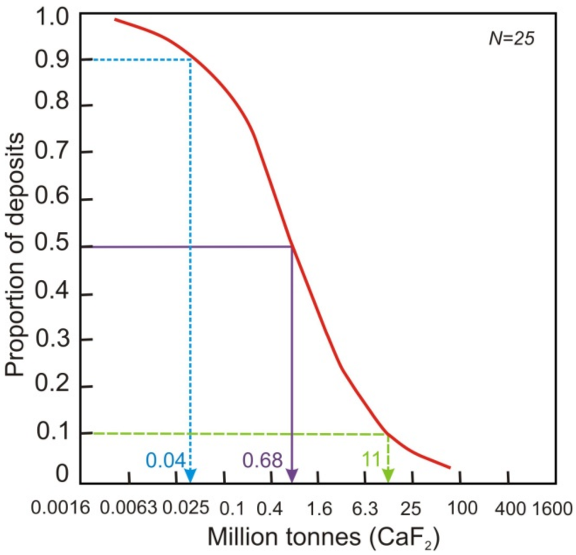

Figure 9. Fluorite vein tonnage model can be used in mineral potential evaluations and in early screening of fluorite development projects. From Orris (1992). It complements the grade model (see Figure 8).

The shape, orientation, depth of mineralization and geotechnical parameters of the mineralization and host-rock are also important. The knowledge of these parameters helps to determine if the mineralization can be mined at profit and by what method. Today, depending on above factors, fluorspar miners use surface or underground mining methods and in some cases rely on a combination of both of these methods (Figures 10 and 11).

The texture, mineralogy and chemistry of the ore (mine run) are reflected in the silica, sulphur, calcite, and minor and trace element content of fluorite concentrates. They have indirect impact on the marketability of products from a given fluorite deposit. For large, medium to low grade ore deposits with high dilution factor and/or containing minerals with similar properties to fluorite, the processing circuit could be complex. Heavy-media separation, followed by differential flotation (for separating fluorite from sulphides and other common gangue minerals), combined with other methods to upgrade low-grade ores are common practice. In some cases, fine-grain flotation concentrates (or dust) are pelletized or briquetted to satisfy consumer needs.

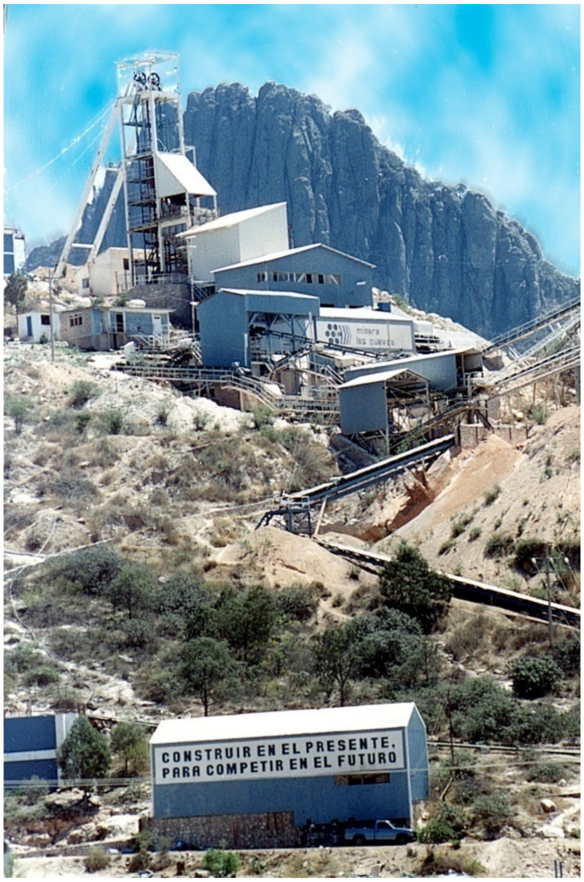

Figure 10. Underground Fluorspar Mine located near Potosi, Mexico; photo used with permission of MEXICHEM.

Figure 11. Large open pit fluorite mine, within the giant Vergenoeng fluorite – iron oxide - fayalite pipe, South Africa. Pick-up truck for scale (circled). Photo used with permission of Vergenoeg Mining Company Ltd.

Most known economically significant deposits, able to provide coarse and high-grade fluorite-rich ores (or usable fluorite concentrate requiring simple metallurgical processing), able to compete with low cost historical exports from China are currently in production or were exhausted. Such deposits remain primary exploration targets worldwide. Large tonnage, lower grade and/or metallurgically more complex deposits are currently being investigated.

Depending on concentrations, grain size, mineralogy and textures, the presence of metallic minerals within fluorite ore may either improve or impair the economic viability of a deposit. In extreme cases, if metallurgical and economic parameters are satisfied, fluorspar may be recovered as a by-product of metal mining (for example lead-zinc veins, Mississippi Valley-type Pb-Zn deposits, iron-fluorite, barite-fluorite, REE-fluorite and uranium-fluorite deposits), where fluorite accounts for 10% or more of the ore. Fluorite is also recovered from tailings associated with historic mines in Mexico and Europe.

Fluorite Ores and Grades of Concentrate

Fluorite is present in a wide variety of ore deposits and, depending on the type of ore, commercial fluorspar concentrates contain mineral impurities such as calcite, dolomite, quartz, chalcedony, barite, celestite, various sulphides, phosphates, and others. The textures and mineralogy of ore determine the type of the concentrate that can be produced. Commercial fluorspar products are subdivided into ceramic, metallurgical and acid grades (Harben, 1999; British Geological Survey, 2005). The type of impurities and textures of the ore determine which of these grades can be produced from a given orebody.

Ceramic grade is commonly fine-grained and subdivided to No.1 product - 95-96% CaF_2, < 3% SiO_2, <0.12 ferric oxides, low calcite content and traces of Pb and Zn. No.2 product contains 85% to > 90% CaF_2.

Acid grade concentrate is also fine-grained and it must contain more than 97% CaF_2, < 1.5% SiO_2, 0.03 – 0.10% S (as sulphide or free S), <12 ppm As, 100 - 550 ppm P, plus low concentrations of Pb, Cd, Be, $CaCO_3$ and moisture (Harben, 1999). Acid grade concentrate is produced by the flotation process so its particle size is typically 100 mesh or lower (Figure 12).

Figure 12. Acid grade fluorspar concentrate; particles are less than 1 mm in size. Photo used with the permission of MEXICHEM.

Figure 13. Metallurgical grade fluorspar concentrate. The ruler is in inches and centimetres for scale. Photo used with the permission of the MEXICHEM.

Metallurgical grade concentrate must contain > 80% CaF_2, < 15% SiO_2, and the material must pass through a 1.0 to 1.5 inch screen while less than 15% of that material should pass through a 1/16th inch screen (Harben, 1999). In the USA, metallurgical grade fluorspar needs to have over 60 effective % fluorspar ($\{\%CaF_2 - [2.5 \times \%SiO_2]\} > 60$). Fines meeting or slightly exceeding chemical specifications of metallurgical grade products may be pelletized or briquetted and used as a substitute for the traditional "gravel-type" fluorspar products seen in several segments of the metallurgical industry (Figure 13).

While acid grade fluorspar concentrate is commonly considered by industrial users as the highest quality finished product (> 97% CaF_2), it is commonly produced from lower grade deposits than metallurgical grade concentrate or as a byproduct of metallic ore processing. This is possible because acid-grade concentrate does not have to be coarse-grained and therefore fine-grinding and flotation can be used for upgrading.

To produce metallurgical grade ("gravel-type") concentrate (> 80 % CaF_2, having 10 to 75 mm particle size), a rather exceptional deposit is required, and/or the ore must be extracted by selective (in many cases small scale) mining, which in the past resulted in high-grading of a number of large deposits. To preserve large sized fluorite particles (Figure 13), the mine run is only crushed, sorted (sometimes by hand or upgraded using a heavy media separation circuit), screened, dedusted and dried before packing and shipping. However, some larger producers are resorting to pelletizing and briquetting of sub-acid grade fluorspar fines (including dust) to produce a substitute for traditional coarse-grained metallurgical grade product shown on Figure 13.

Fluorspar Resources

Detailed technical review of exploration, mining and processing methods is outside the scope of this paper and use of geological models is appropriate only when addressing seasoned industrial mineral geologists. For this reason, the approach used here to assess the fluorspar resource availability is based on an existing compilation of Miller (2008a). This compilation is the best data set that was publicly available at the time of writing. Data provided by Miller (2008) regarding fluorspar resources can be conveniently summarized in Figures 14 and 15. There is probably a large margin of error incorporated into these estimates. It would be a highly unlikely coincidence that world reserves would be exactly 50% of the world "reserve base".

To fully appreciate the discussion on the availability of fluorspar raw materials, it is imperative to understand the significance of the terms "*resource*", "*reserve*" and "*reserve base*" as defined by US Geological Survey (2008). The term "resource" refers to "a concentration of naturally occurring solid,

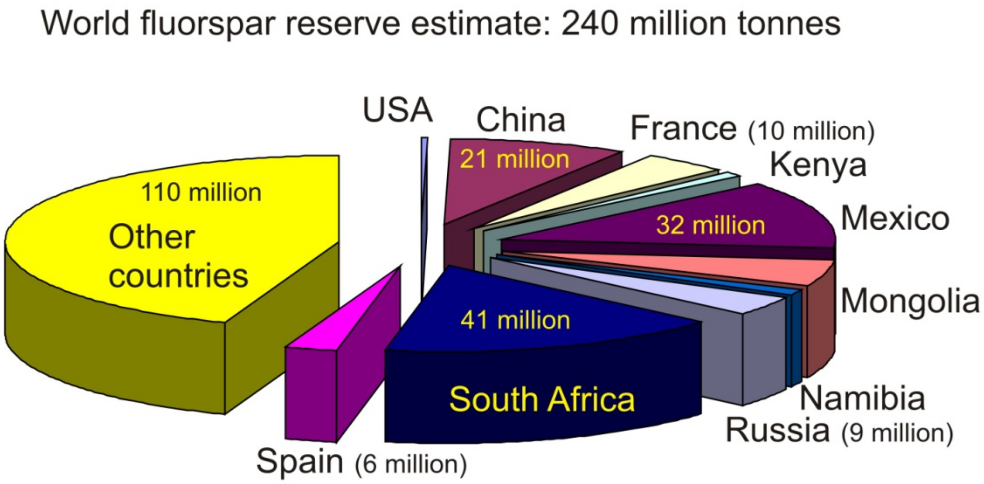

Figure 14. Geographic location of known fluorspar reserves (data reported by Miller, 2008a).

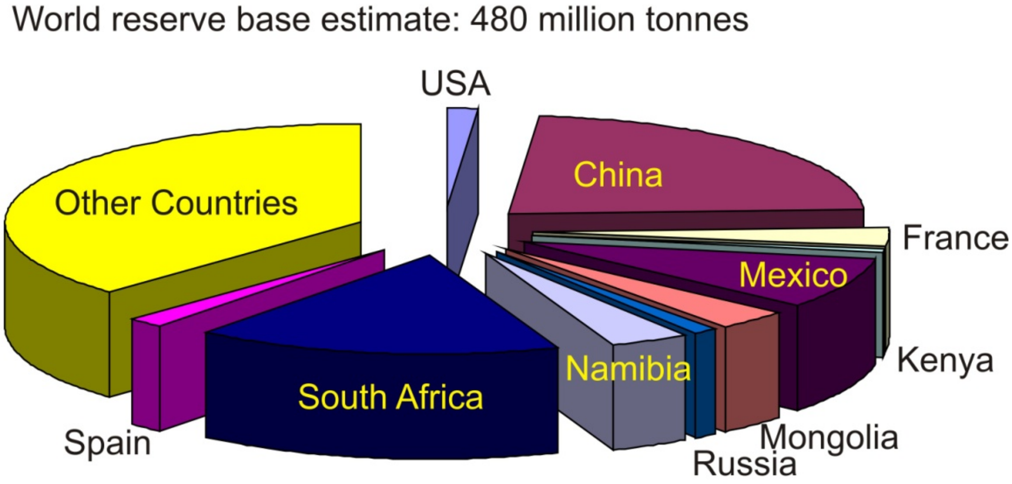

Figure 15. Geographic location of the fluorspar reserve base (as reported by Miller, 2008a).

liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible".

The term "*reserve base*" refers to "an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth". The reserve base is the in place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently sub-economic (subeconomic resources)".

"*Reserves*" are "a part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials".

Figure 16 shows the ratios of "reserves"/yearly fluorspar production and "reserve base"/yearly fluorspar production for major fluorspar producing countries and the rest of the world. These ratios can be used as crude short term and medium term indicators of *in situ* fluorspar availability. South Africa has the best potential to remain the major fluorspar producing country over the short- and long-term.

South Africa stands out because its reserves and reserve base could sustain the 2007-level production (295 000 tonnes/year) for 139 and 275 years, respectively. Morocco is currently a major producer, yet Miller (2008a) does not have information regarding fluorspar reserves or reserve base in that country. The statistics for Russia are also incomplete, as the reserves are described only as "moderate". In the absence of better data we have extrapolated Russia's reserves to be half the size of the reserve base. Some other fluorspar producing countries listed by Miller (2008b), not shown on Figure 16 for similar reasons, are Brazil (63 700 tonnes), Iran (65 000 tonnes), UK (40 000 tonnes) and Germany (53 000). The production figures used in the calculation are those reported by Miller (2008b). The gaps in the data, as illustrated by examples of Morocco, Russia and other producing countries remind us that any interpretation of the data must be considered as semi-quantitative at best.

Figure 16 also shows that the ratio of reserves/yearly production for China is much lower (< 8 years) than for other major fluorspar producing countries. This anomaly requires additional investigation to verify if it is real or apparent. In the past, countries with totalitarian regimes commonly "liberally" reported resources in general as reserves. Today, the inverse may be also true and some of the reserves may not be reported. It is also possible that Chinese reserves were high-graded during prolonged periods of low fluorspar prices. If the data are correct, assuming that there was no new exploration work going on in China, this country would have less than 8 years of ore reserves. Similarly, China's reported reserve base may sustain 40 years of production (at 3.2 million tonnes/year).

It is also interesting that France, a historical major producer practically discontinued its fluorspar production in 2006. All other producing countries appear to have enough reserves to last over at least 20 years and their reserve bases could sustain production at their 2007 levels for more than 30 years. Figure 16 is showing that there are over 367 and 600 years of supplies for the category "other" countries. This may potentially provide consumers with a false sense of security. These numbers are ratios of reserves/yearly production and reserve base/yearly production, and their meaning may be misinterpreted if the reader forgets that these "other" countries represent combined production of only 300 000 tonnes of fluorspar in 2007. The last entry in Figure 16, identified as "world" provides a global picture. The ratios world reserves/world yearly production and world reserve base/world yearly production indicate that known world reserves and resource base could sustain global world production of 5.31 million tonnes of fluorspar/year for a period of 46 years and 90 years respectively, assuming acceptable level of market elasticity.

The geographic shift in fluorspar production from China to the rest of the world will be also supported by fundamental economic changes. In the past, fluorspar producers in developing countries, especially China, benefited from low energy and labour costs and were encouraged to export raw materials such as fluorspar. The historical advantages that contributed to make China such a dominant fluorspar producer are gradually disappearing. Given the fact that a large proportion of the fluorspar reserve base is located outside of China (Figure 14),

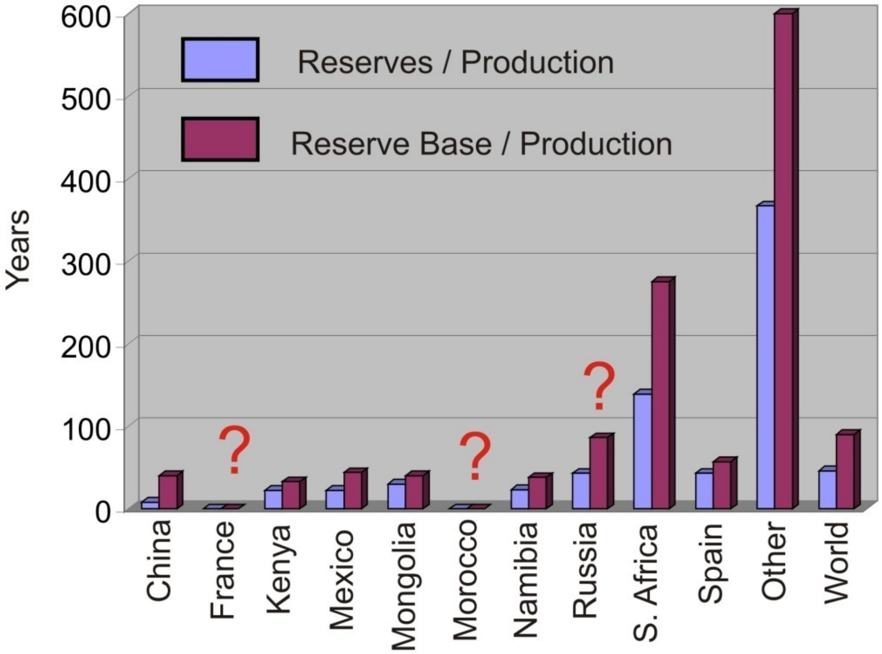

Figure 16. Ratio of "reserves" and reserve base" to the 2007 yearly production can be used as crude relative indicators of fluorspar availability. The ratio involving reserves looks at near term availability and ratio involving reserve base provide a longer term estimate. The accuracy and precision of these estimates are ultimately dependent on the quality of the database (in this case we use the reserves and reserve base data from Miller (2008a) and yearly productions as reported by Miller (2008b)).

and relatively high fluorspar prices prevail, we may expect a restart of previously closed fluorspar mines and possibly development of new ones in Africa, North America and Europe. It is also important to realize that the long-term relationship between fluorite demand, production level, reserves and reserve base are elastic and continuously adjusting. As the demand for fluorspar increases, so does its price and some of the deposits previously deemed uneconomic or sub-economic could become profitable mines.

In the short term, China will remain a dominant fluorspar producer and consequently will have an ability to influence fluorspar prices. The relation between supply and demand may not be entirely elastic and some shortages in specific fluorspar products may develop. In developed countries it takes several years to bring a new mine into production. Discussion with representatives of current fluorspar producers from Mongolia and Brazil suggest that the permitting procedure for a fluorspar mine in these countries takes less than a year. There are several fluorspar producers that may take advantage of current high fluorspar prices to expand their share of the market. Any fluorspar shortages are likely to be short-lived. The size of reported reserve base suggests that as long as fluorspar prices remain high, and the market is growing or stable, a number of new development projects could start. How many of these new projects will be successful over the long term will depend on the future trend of the fluorspar market. The primary fluorspar projects with high (or at least above average) tonnage and grade, metallurgicaly simple ore, with sound technical financial backing and a strong management team linked to fluorspar consumers, will reach production stage and survive a major economic downturn. Availability of infrastructure and proximity to low transportation cost or proximity to the market are other important considerations.

The compilation of Miller (2008a) is not detailed enough to determine what portion of the reserve base is compatible with production of metallurgical grade fluorspar, but as previously indicated, it is more difficult to find ore deposits that could supply coarse (gravel-type) metallurgical grade (without briquetting or pelletizing) than to find resources able to supply fine-grained acid grade fluorspar.

Fluorspar in British Columbia

There are over 78 fluorspar occurrences in British Columbia (Figure 17). Information regarding fluorite and fluorine in British Columbia is summarized by Pell (1992) and MINFILE (2009). The BC Regional Geochemical Survey provides information regarding fluorine concentrations in water. Such data sets are useful in the early stages of exploration for fluorite and a variety of metallic deposits. Rock Candy (fluorite); Eaglet (fluorite ± molybdenum ± celestite [$SrSO_4$]); Rexspar (fluorite ± celestite), several occurrences in the Laird River district (fluorite ± witherite [$BaCO_3$], barytocalcite, and barite) and

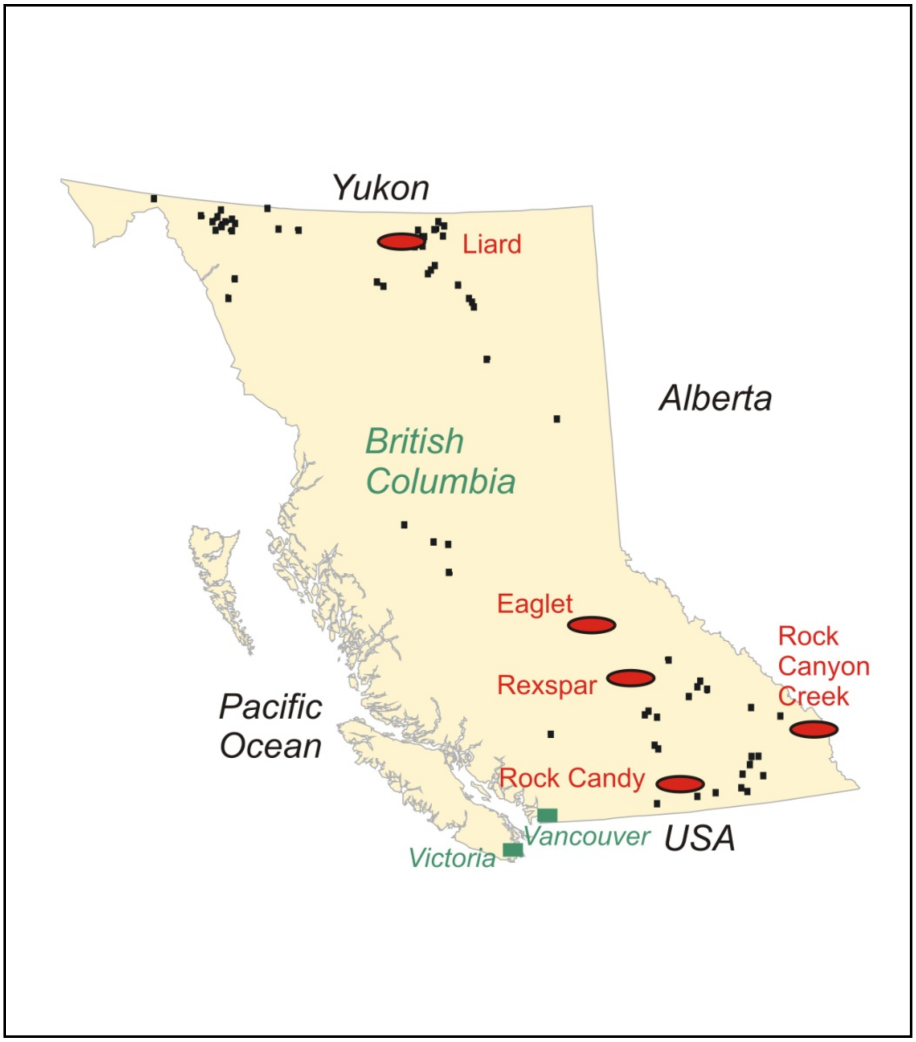

Figure 17. Geographic distribution of fluorite occurrences in British Columbia (black squares). Deposits dicussed in this paper are shown by red ellipses.

Rock Canyon Creek, also called Deep Purple (Fluorite ± Rare Earth Element [REE] ± precious metals) are some of the better known fluorite-bearing deposits located in British Columbia. Descriptions of these deposits are summarized in MINFILE and Simandl (2009). British Columbia has excellent geological potential in terms of fluorspar.

Conclusion

The nomenclature and regulations used for reporting of ore reserves and resources in many of the developing countries do not follow the same standards as in western countries and are not comparable to those of Canadian National Instrument 43-101. Consequently, legitimate concerns may be raised regarding ore reserve estimates from developing and especially totalitarian countries.

Assuming that world reserve and resource base data compiled by Miller (2008a) is essentially correct, there should be no long term in situ shortage of fluorspar raw materials. This is a reasonable assumption, unless the balance between supply and demand is affected by new technology requiring fluorite or fluorine, or unexpected conflicts or upheavals impacting major fluorspar producing countries. In the medium to long term, Mexico, South Africa, Mongolia and other countries (including Canada) with established fluorite reserves or reserve bases will start or increase their production to fill the vacuum if reductions in China's fluorspar production persist.

Acid grade concentrate, a fine-grained and highly processed product, accounts for the bulk of the fluorspar market. Such concentrate may be derived from a wide variety of primary fluorspar deposits or recovered as byproduct of metal mining. New deposits containing ores amenable to production of metallurgical grade fluorspar, which is characterized by larger particle size, will be more difficult to find. Based on current fluorspar market conditions and reduced fluorspar reserves in China, the timing appears to be favorable for exploration and development of fluorspar resources outside of China, including those in British Columbia. Rock Candy, Rexspar, Eaglet, Rock Canyon Creek and the Liard area deposits can be considered as examples (Simandl, 2009). However, the development of new deposits may be tempered by the effect of the current world economic slowdown that will probably, at least temporally, reduce demand for fluorspar products. Increased environmental pressures on the fertilizer industry will moderate long term growth in fluorspar demand through increased recovery of fluorine from phosphate rocks.

Acknowledgements

The author extends his appreciation to Mr. Hector Valle Martin, the Director General / C.E.O of MEXICHEM in Mexico, and Mr. Denis Cook of the Vergenoeg Mining Company (PTY) Ltd. in South Africa for the permission to use their photographs. Earlier versions of this manuscript benefited from reviews by Tania Demchuk, Kirk Hancock and Mathew Tanner from the British Columbia Ministry of Energy Mines and Petroleum Resources and by Suzanne Paradis from the Geological Survey of Canada. The author was assisted in the field by Alan Duffy, a recent graduate from the Trinity College, Dublin, Ireland. Field collaboration with Chris Graff of the Spectrum Mining Co. and Bob Jackson owner of the Rock Candy Mine was greatly appreciated.

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