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Donald F. Sangster earned a B.Sc. (Chemistry) at Bishop's University, a B.Sc. and M.Sc. (Geology) at McGill University and a Ph.D. (Geology) at University of British Columbia. He was hired by the Geological Survey of Canada in 1964 as an economic geologist and served in that position until retirement in 1995 after reaching the level of Research Scientist 5. He then continued as Emeritus Scientist until 1997. He was Head of the Mineral Deposits Section from 1971 to 1976. In 1986, the University of Ottawa appointed him Adjunct Professor, a position he held until 1995. After serving several positions within the Society of Economic Geologists, he was elected President of the Society for the year 1994-95. He was awarded the Duncan R. Derry Gold Medal by the Geological Association of Canada (1981), the Silver Medal by the Society of Economic Geologists (1984), the Past President's Medal by the Mineralogical Association of Canada (1986), and the Logan Medal by the Geological Association of Canada (1998).

Notes on OPERATION SEPTEMBER

Operation September - initiation, methodology, and results

The directive initiating "Operation September" landed on our collective desks on or about April Fool's Day, 1972 although it was not called Operation September at the time. I don't recall ever seeing the original directive so I don't know what its official name was if, indeed, it ever had one. Also, here, and throughout the remainder of this presentation, "our" refers to those of us in the Mineral Deposits Section - in those days the GSC still had sections and section heads.

Apparently the government of Canada needed quantitative information regarding the known and estimated unknown resources of seven commodities (Cu, Pb, Zn, Mo, Ni, Fe, and U) for the entire country and they needed to know it by September of the same year - hence the name. "Quantitative" meant that parliament wanted the known and estimated unknown resources to be presented in terms of tonnes of metal. Minerals export policy was being formulated and parliament wanted to be assured we had sufficient long-term resources to satisfy present and

future domestic needs. As I understood it, the directive also instructed that the project be a joint effort of the GSC, Mines Branch (MB), and Mineral Resources Branch (MRB). The directive further stated that the lead agency in this unholy triumvirate would be the GSC which, apparently, caused much anguish within MRB. Such anguish was understandable as they were the government's mineral economists (geo-economists?) and, at the time, held the only known national databank of commodity reserves and resources. Thus they naturally, and understandably, assumed they would be the "obvious" agency to fulfill the directive. Additionally, to my knowledge, the directive contained no instructions or recommendations regarding form, format, or content of the final report. As will be explained later, this apparent lack of fore-thought with regard to reporting format resulted in needless extra effort once the report was submitted.

Once we (i.e., Mineral Deposits Section geologists) realized the magnitude of the directive, our initial reaction was "it can't be done". This response was conveyed upwards to "whomever" and the counter-response was "Fine, if the geologists won't do it, the economists will". This scared the hell out of the economic geologists and resulted in an immediate about-face in attitude.

To put our initial response in perspective, it must be realized that, on April Fool's Day, 1972, we were a very small group, barely tolerated by GSC management for whom regional mapping was the "holy grail" of the GSC as matters relating to mineral resources were seen to be a provincial responsibility. Furthermore, most, if not all, our activities at the time were in the form of small, detailed, and local research of selected individual mineral deposits (e.g., trace element studies, isotopes, mineralogy, etc.). Accordingly, none of us had much awareness of, or interest in, the "bigger picture" of what deposits existed in Canada, where they were, what they were, or their grade-tonnage characteristics. Adding to our confusion and anxiety in the face of the April Fool's Day directive was the fact that none of the three participating agencies, least of all the GSC, had a methodology at hand for making qualitative, let alone quantitative, estimates of undiscovered resources in the hinterland areas of the country. Furthermore, the directive provided neither extra support staff nor additional funding for this monumental and unique project.

Once it became clear that the GSC response would be spearheaded by the Mineral Deposits Section, our immediate action, in the face of the exceedingly short time-line, was intuitive and non-negotiable. It comprised three main factors:

1) although the directive required information be reported as mineral commodities (i.e., chemical elements), our methodology would be based on individual deposits and deposit-types expressed in terms of recognized geological provinces (e.g., Abitibi Belt, Sudbury Basin, Labrador Trough, etc.);

2) in those days, individual GSC economic geologists were assigned (or they selected) a specific mineral commodity (or commodities) in which to specialize. This meant that the seven chemical elements requested in the original directive were going to be covered by five people as follows: Sangster (Zn, Pb), Kirkham (Cu, Mo), Eckstrand (Ni), Gross, (Fe), and Little (U). Thus the entire GSC response became the responsibility of these five geologists; and,

3) holiday leave for these five people, several support staff, and selected managers would be cancelled for the summer of 1972.

The methodology evolved as data were being gathered. First priority was given to the assembly of known reserves in operating mines and known prospects. The existing databank of MRB was invaluable for this phase of the operation and required much closer co-operation between MRB and GSC personnel than had been experienced to that time. MRB data, however, was, by its nature, restricted to quantitative data voluntarily supplied to MRB by the mineral industry. Many companies (e.g., INCO) refused to provide MRB with any reserve data, restricting their reporting simply to past production. For those companies that <u>did</u> report, however, their data were several years out-of-date. We soon realized the inadequacy of the MRB databank for purposes of Operation September and quickly, and intuitively, decided to gather our own reserves and resource data by directly contacting individual mines and companies. In spite of never having approached companies in this manner before, our requests for confidential information were, for the most part, well received by our industry contacts. This pleasant reception I attribute to several causes: i) our economic geologists enjoyed a large measure of respect through personal contact with mine and exploration geologists; ii) we stressed that information so provided would be, and would remain, confidential; iii) we explained that we

were collecting information for a specific purpose (i.e., to assist in formulating export policy) and were not simply gathering information for information's sake; iv) much of the information was delivered orally as there was neither time nor incentive to wait for official, written, corporate clearance of the data. This personal approach to the gathering of reserve and resource data to augment that provided by MRB, although it enjoyed a large measure of success, had its limitations. Large mines, for example, seldom drilled off their entire orebody but, instead, only drilled enough to ensure stockholders that the mine held "XX" years' of reserves. Several companies, by corporate policy, withheld publication of reserves and resources for fear (real or imagined) of being taxed on ore-in-the-ground rather than on production. In the case of iron, large deposits of this commodity exist as iron-formation which is essentially a stratigraphic unit rather than a discrete entity such as a sulphide deposit. Although the geographic extent of iron-formation can be traced through airborne or ground magnetic surveys, the iron-bearing units are seldom totally drilled-off to gain a quantitative measurement of the total commodity. Thus, the data for known reserves and measured resources of the seven Operation September commodities were recognized as being minimal rather than actual.

Once reserves and measured resources of known deposits had been compiled, attention turned to the daunting task of estimating unidentified resources expectable in mining areas as well as in the Canadian hinterland. At this point, special mention must be made of the situation with respect to iron and uranium. Compilation of known reserves and resources of these commodities, as well as estimates of unidentified resources, had, to a large degree, already been done before Operation September. This was due to the fact that Canadian resources of these commodities had been compiled in agreement with international standards and classifications.

For the five remaining commodities, estimates of undiscovered resources were largely made on the basis of comparative geology, i.e., comparing the geology of the target area(s) with that of well-documented mining districts. A proper comparison, of course, requires identification of not only the broad, regional characteristics of mining camps but also the detailed specifics associated with each deposit-type, otherwise known as *metallotects*. Many target areas, unfortunately, lacked even the broadest of geological information on which to base resource estimates. For example, existing geological maps of many northern areas (e.g., those mapped by helicopter-borne surveys) would simply describe large tracts of land as being "mixed basic and felsic volcanics". Metallotects such as volcanic breccias, concentrations of felsic volcanics, or

exhalative units were simply not recorded. In some cases, participants in the mapping of such areas might still be available for direct questioning but, for the remainder, comparative geology was, at best, essentially a guess.

Once the process of comparative geology was completed for each target area, the deposit-type appropriate for the geology was selected. In addition to the lack of detailed geology of the target areas, this step was further complicated by several factors, chief among them being:

i) in 1972, many of the deposit-type models widely accepted today were still in the process of being established. For example, SEDEX (Sedimentary Exhalative) deposits were still regarded as black-shale replacements, MVT (Mississippi Valley Type) deposits were assumed to be related to unconformities in carbonate rocks, the first description of the major characteristics of VMS (Volcanic Massive Sulphide) deposits and their metamorphosed equivalents had just been published that year, the distinction between porphyry copper- versus molybdenum-bearing granitic intrusions was poorly understood, etc., and,

ii) although the three "sulphidic" geologists (Sangster, Kirkham, Eckstrand) had a broad knowledge of Canadian deposits, proper estimation of undiscovered commodities required an understanding of the geological characteristics of deposit-types outside the country. Consequently, while simultaneously compiling the reserves and resources of known Canadian deposits and trying to identify metallotects in poorly-mapped target areas, the commodity geologists were also busy searching the literature for good descriptions of deposit-types not well represented in Canada and which therefore had not been personally examined by GSC economic geologists. Examples included SEDEX-type Zn-Pb deposits, Kupferscheifer-type copper deposits, and Noril'sk-type nickel deposits.

Within each target area, commodity geologists estimated the deposit-type(s), number, and grade-tonnage characteristics of undiscovered deposits judged to be present in that area. The estimation was largely influenced, if not determined, by two main factors:

i) the extent to which the geology of the target area compared to the geology of known mining districts of each deposit-type; and,

ii) whether or not mineral occurrences of that commodity (-ies) were known in the target area.

Each known and estimated undiscovered deposit was then placed in one of four categories of a reporting grid consisting of a horizontal and vertical axis. The horizontal (X) axis

described four classes of "assurance of existence" decreasing from Class 1(already discovered), through Classes 2(additional expected in mining areas), 3 (additional prospective in areas of known mineral occurrences), and 4 (additional speculative in virgin areas). At this point, the deposits, except mono-metallic deposits such as those of Fe and U, had not been separated into commodity metals.

Once the deposits, known and undiscovered, had been figuratively placed in one of the four existence classes by GSC economic geologists, the next step was to rate each deposit, in turn, in terms of "exploitability levels" (the vertical "Y" axis of the reporting grid). The Y axis comprised three levels as follows: Level A (presently exploitable on discovery), Level B (more than 50% probability of being exploitable before the year 2000), and Level C (10 to 50% probability of being exploitable before the year 2000). This rating of exploitability level was accomplished by joint meetings between GSC economic geologists, MB staff experienced in mineral dressing, and MRB geo-economists. The process required the GSC economic geologist(s) to figuratively lay on the table each individual deposit, in turn, and describe the general geological features, contained commodities, mineralogy, texture, inter-mineral relationships, and approximate locations of known and estimated undiscovered deposits. Judgments as to mineral dressing feasibility and economic viability were then made by MB and MRB personnel, respectively, resulting in each deposit (with its attendant grade-tonnage) being placed in one of the three exploitability levels. As previously explained, the internationally-determined categories for Fe and U did not easily fit into the reporting grid established for the other five commodities so that, to a large extent, Fe and U retained their international existence/exploitability classifications.

At this point in the project, the remaining commodities were still being grouped according to their natural geological occurrence (i.e., Zn-Pb, Cu-Mo, Cu-Ni, Cu-Pb-Zn, etc.). This was necessary in order for the exploitability rating to take place. Once this process was completed, however, separation of the geological groupings into separate commodities could commence. To accomplish this in the days before desk-top computers required Robert Laramée to personally write a computer program to convert grade-tonnage figures into tonnes of metal for each commodity, all the while keeping track of which existence class and exploitability level the newly-converted figure(s) belonged. The result of all this was a series of reporting grids for each of the seven metal commodities for each geological province in Canada. These reporting grids,

together with explanatory text and (hand-drawn) maps of Canada illustrating geological provinces, were submitted, on time, as the completed Operation September report.

Effects of Operation September within GSC

Although I have no personal knowledge of the extent to which Operation September influenced Canadian mineral export policy (the original stated purpose of the request), I can attest to the fact that the operation had a profound, and long-term, effect on the GSC and specifically on the mineral deposits group of geologists. Some of the actions resulting from Operation September are as follows:

1. No sooner had the report been submitted to "whomever" had requested it than it immediately became politicized. Although the internal reporting areas were geological in nature and, therefore, should have had no effect on formulating a national export policy, within months (as I recall) came the request for the Operation September data to be re-cast into political (i.e., provincial and territorial) regions. This proved to be extremely difficult to do for those geological regions distributed between two or more political provinces (e.g., Abitibi Belt, Grenville Supergroup, etc.). Whereas one could have a certain level of confidence that a given geological region contained "X" number of deposits of a given type, to further distribute this "X" between two provinces, particularly for regions lacking detailed geology, simply increased the level of uncertainty. As I recall, this "political re-cast" of Operation September was published by MRB.

2. Within the Mineral Deposits Section (and its later morphological equivalents), particularly among the original Operation September participants, documentation of mineral deposit characteristics and development of descriptive deposit-models came to take priority over detailed mineral deposits research. This over-view approach manifested itself, years later, as DNAG (Decade of North American Geology) Volume P-1, otherwise known as "Geology of Canadian Mineral Deposit Types". It's important to note that this overview was described in terms of deposit-types, rather than descriptions of specific Canadian mineral deposits as all previous versions of EG1 (Economic Geology 1 – published by GSC) had been. This change I attribute largely to Operation September.

3. Switching from detailed, single-deposit research to the broader objective of developing deposit-models, required a subtle change in laboratory equipment to effect these studies. Prior to

Operation September, a major activity of mineral deposits support staff was the production of polished sections for microscopic identification and study of mineralogy and texture. Following 1972, however, increasing importance was given to the collection and study of polished slabs for the broader purpose of documenting (usually in the form of photographs) common internal features of deposit-types (e.g., internal layering, metamorphic effects, etc.). Eventually, our labs acquired three polishing tables in addition to the two machines originally purchased for making polished sections. Specialized equipment for photographing polished ore slabs, rather than photomicrographs, had to be purchased.

4. Because GSC had taken on the role as lead authority in the estimation of undiscovered resources, the advantage of establishing and maintaining our own files on mineral deposits, both domestic and foreign, quickly became evident. This resulted in several commodity geologists initiating and maintaining extensive "paper files" of both domestic and foreign deposits. These files, which contained not only geological information but also data regarding grades and tonnages, were valuable as instant sources of information useful in building deposit models and resource estimations.

5. Although Operation September was the first multi-commodity resource estimate, it was by no means the last. In the years following 1972, realizing the extent and level of mineral deposits expertise within GSC, other Canadian agencies began requesting estimates of undiscovered resources. Notable among these was Parks Canada (who had been commanded by parliament to obtain resource estimates from GSC before establishing new park boundaries) and a variety of aboriginal groups requesting information on potential mineral resources for inclusion in present and future land claims.

6. The final Operation September report was classified as "confidential" and its results have never been made public. GSC management, however, decreed that all future resource estimates should consist of published reports. I always interpreted this as an effort on the part of GSC to retain and promote its "honest broker" image inasmuch as information gathered to satisfy Parks Canada and aboriginal lands claim requests might also be of interest to the mineral industry, particularly since Parks Canada used GSC resource estimates to withdraw land from mineral exploration. If all that Parks Canada and aboriginal groups required were statements of mineral resource potential, this could have been effected in the form of memos from GSC. The decision to "go public" with the resource estimates, however, resulted in extra expense, time, and

effort by the GSC, not only by the mineral deposits geologists but by GSC editors, draftspeople, typists, and publishers.

7. Management, at both the GSC and Departmental level, apparently accepted the principle that proper estimates of undiscovered resources required personal examination of deposits outside Canada. Whereas, previous to Operation September, foreign travel had been severely limited, after 1972 mineral deposits geologists, in particular, enjoyed more than 20 years of extensive and widespread opportunities to examine mineral deposits in other countries. This was effected by several means such as participation in international projects (e.g. IGCP's CCSS – International Geological Correlation Program Project 60, Correlation of Caledonian Stratabound Sulphides), attendance at international conferences with associated field trips to mineral districts of interest, invitations by academia and industry in foreign lands to participate in symposia and theme conferences, as well as requests by GSC economic geologists to examine specific deposits or districts for the sole purpose of obtaining first-hand information on the regional geology and internal features of selected deposit-types.

8. The need to improve methodologies to be used in estimating undiscovered resources was obvious at the outset of Operation September (April) but the imposed deadline (September) did not permit the luxury of experimentation and development of methods to effect the estimates. Following Operation September, however, experiments in method development began to emerge, particularly in conjunction with members of the Geomathematics Section. Notable among these efforts was Project Appalachia, an experiment in relating tonnes of metal to measured areas of favourable rock units.

9. Our own mineral deposits expertise, combined with our experiments in resource estimate methodology, attracted the interest of other countries engaged in similar studies. As a result, we entered into informal discussions with USGS (United States Geological Survey), USSR, Germany, etc. as well as participating in formal symposia on the subject.

10. Although Operation September and most of the resource estimate studies thereafter were based on what I refer to as "passive" information (i.e., previous geological, geochemical, or geophysical information not specifically gathered for resource estimate purposes), it was soon recognized that there was a need to gather targeted information specifically tailored for resource estimates. This was especially apparent for certain areas in the north where key geological and other information were lacking. This resulted in the MERA (Mineral and Energy Resource

Assesments) Project in conjunction with Parks Canada (e.g., geochemical studies on Banks Island).

11. In 1995, the present writer was asked by the then Chief Scientist (J.M. Franklin) to provide "an estimate of how much more of seven major Canadian mineral commodities remain to be discovered". Although six of the seven commodities requested were the same as those in Operation September, the 1995 request dropped Mo in favour of Au. To prepare this report, again with a very short deadline, the writer used the original Operation September data as (thankfully) the request was to present results in terms of geological, not political, provinces. The accompanying text re-iterated many of the same principles (and caveats) as the 1972 report. New estimates for Au were requested from F. Robert and H. Poulsen. Interestingly, these latter authors used essentially the same techniques employed by the rest of us in 1972.

12. In 1997, the writer (by now retired) was again asked by the same Chief Scientist to prepare a series of diagrams illustrating northern Canada's (i.e., north of 60°) undiscovered mineral resource potential. The commodities requested were the same as for the 1995 report and, again, reporting was presented in terms of geological provinces.

Although there are other effects of Operation September that I can think of, I admit I can't remember enough details to describe them accurately. Suffice to say, however, that the fallout from the operation was profound and long-lasting. Without Operation September, I feel that mineral deposits research in the GSC would have died "on the vine" many years ago. It gave us money, manpower, and prestige that reflected well not only on our own little group of experts but on the entire GSC organization.

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