GOVERNMENT CANADA

STATEMENTS AND SPEECHES

INFORMATION DIVISION
DEPARTMENT OF EXTERNAL AFFAIRS
OTTAWA - CANADA

No. 49/30

CRITICAL MINERAL SHORTAGES

An address delivered at a plenary session of the United Nations Scientific Conference on the Conservation and Utilization of Resources, on August 18, 1949, by Dr. H.L. Keenleyside, Deputy Minister of Mines and Resources, and Commissioner of the Northwest Territories.

I am deeply sensible of both the honour and the responsibility which I accepted in agreeing to prepare a statement on critical mineral shortages for a plenary session of this Conference.

It would be difficult to exaggerate the importance of the subject. The significance of minerals in providing the material basis for the economic life and social organization of humanity has long been recognized. Indeed, historians and archaelogists commonly designate the major divisions of human history by reference to the mineral products which were most characteristic of the successive eras. Thus we have the Paleolithic and Neolithic Periods and the Copper, Bronze and Iron Ages.

Contemporary civilization, beyond all preceding experience, depends for its continuance on the minerals which permit and sustain its existence. The growth and concentrations of population, the frequency and speed of movement and transport, the extent and quality of human control over the forces of nature are all directly dependent upon the discovery and utilization of mineral resources. It is, therefore, of prime importance that we should have as accurate information as can be obtained about the extent of the available reserves in this field.

It will be obvious to all those who have given thought to the subject that a single paper can do no more than outline in general terms the facts of so vast and complicated a subject. However, even generalizations are difficult because our information is so inadequate. Both scientists and economists have boldly adventured in this field and many volumes have been written on particular aspects of its problems - especially within the last ten years. But in most cases the result has been simply to underline the conclusion that our knowledge of the facts is so meagre as to make any precise estimate or detailed and dogmatic forecast either impossible or else of most dubious validity.

Estimates of the general position have varied all the way from a strong conviction that new sources of supply and new techniques of exploitation will always keep ahead of human demand to the contrary view that the standard of life now enjoyed by the more industrialized nations is in danger of early collapse through the exhaustion of essential resources.

Optimistic observers point out that there is to-day no serious or general shortage of any essential metallic or non-metallic mineral product. They recall the way in which discovery has kept abreast of increasing demand in the past, and argue that new discoveries, combined with increased efficiency in methods of processing and utilization, will be adequate to meet any foreseeable future needs.

Those who take the more pessimistic views rightly emphasize that mineral resources, as contrasted with those of the animal and vegetable kingdoms, are wasting assets; they are not replaceable. Nature has supplied a certain amount of metal and mineral content in the crust of the earth and when the utilizable portions of this are exhausted, either by waste or by beneficial use, it cannot be restored. The current rates of consumption present an altogether new problem for which past experience gives no assurance of a solution.

Scientists and industrialists agree on the necessity of maintaining an ample supply of minerals and metals if contemporary forms of civilization are to be maintained or if further progress is to be achieved along lines already defined. Iron, copper, lead, zinc, nickel, aluminum, magnesium and other base metals are by definition fundamental to our way of life. Almost equally important are such alloying metals as manganese, chronium, molybdenum and tungsten, which are essential to the steel industry. The industrial minerals - limestone, sulphur, salt and fluorspar - supply the raw materials for much of the world's chemical industry, while the mineral fertilizers, phosphate rock and potash, are of growing importance in agriculture. Without these, or effective substitutes, large segments of the prospective population of the earth will be condemned to lives of misery and degradation.

The implications of these facts raise a problem so vast and of such universal incidence that in a sane world they would be made the immediate subject of common study and co-operative planning. Unfortunately, the society in which we live is, as yet, very far from having reached that degree of sanity. It is true that some measure of co-operative activity does exist among scientists and that this could readily be expanded if international political and social conditions would permit. Unfortunately, the current trend would seem to be in the opposite direction. Of this the clearest example is to be found in the difficulties that are being experienced in adapting atomic energy to beneficial rather than to destructive uses. In the race between education and catastrophe, education is falling farther and farther behind.

Unhappy as the situation is, we can derive some meagre satisfaction from such gatherings as that upon which we are presently engaged. Whatever the ultimate results of this Conference, we will at least know that here a co-operative international effort has been made to look at the whole problem of world resources in terms of the general welfare. This Conference may not represent a long step forward but at least it is not an illustration of the contemporary international practice of walking backwards.

II

Before commencing a more detailed examination of the problem with which we are faced it would, I think, be well to spend a moment in defining terms. For the purpose of this discussion it is assumed that a "critical shortage" means a shortage of such proportions that the essential needs of the world cannot be met and that the material progress of humanity must, in consequence, be slowed down or directed towards new objectives. I do not include among the "essential needs" the requirements of war. If humanity finds it impossible to avoid war, we may as well assume that we shall be interested in survival rather than in progress. Nor do essential needs include an obstinate adherence to custom or convenience. If a plastic will take the place of a metal in any particular function, the use of metal in that function is not an essential need.

Consideration should not be given to temporary shortages which, like temporary surpluses, may result from changes in the business cycle. It is only by studying the long-term requirements that significant conclusions can be reached.

Nor should problems of national self-sufficiency be allowed to intrude. In scattering its beneficence nature has not taken note of national boundaries, and it is to be hoped that eventually our economic and political systems can be so adjusted as to ensure an equitable international distribution of mineral and of other resources.

Examined in these terms it is quite clear that there are in the world to-day no critical mineral shortages. But this temporary condition should not be allowed to induce a false optimism as to the future. The warning signals are flying. In a matter of this importance we cannot afford to do too little; we must not postpone our studies until too late.

III

As has already been indicated, and as must be constantly recalled, we are hampered in our consideration of this subject by the fact that there are no reliable and complete statistics covering either the extent of our mineral resources or even the rate at which they are being currently consumed. This is true nationally and even more true of the international scene. Consumption fluctuates from year to year in accordance with the industrial activity prevailing in the individual countries and in many of these the statistical information available has only a nominal or shadowy relationship to the material facts. Our difficulties are increased by the particular consideration that there are no recent figures available, except in isolated instances, in regard to either reserves or consumption in the U.S.S.R. Any attempt, therefore, to estimate the world position must be critically viewed in the light of these gaps in our knowledge. Yet in this case ignorance is dangerous.

We do know, with reasonable accuracy, what proportionate amounts of aluminum, iron, magnesium, titanium and other metals are to be found in the crust of the earth. We know, for example, that for every 100 units of lead there are

200	units of zinc
400	units of uranium
480	units of copper
1000	units of nickel
1800	units of chromium
32000	units of titanium
248000	units of iron
400000	units of aluminum

The "Big Four" of the metal world - nickel, copper, zinc and lead - are relatively scarce. But this, however interesting, is of little real significance. What is important is the extent to which the various metals are to be found in economically or even in technically workable concentrations. For example, lead, zinc and tin are rarer constituents of the earth's crust than uranium, although usable deposits of the latter are of much less frequent occurrence than are those of the other three metals. It isn't the quantity, it is the concentration that matters.

Among the reasons for our meagre knowledge of our mineral heritage is the fact that in only a few countries has there been any systematic and detailed geological and mineralogical study of the national domain. Even in the United States of America, where more attention has been given to this matter than in any other country, estimates of available resources are recognized as being little better than intelligent guesses. For example, in 1914 the taxable iron ore reserves of the famous Mesabi range were estimated at 1,386 million tons. In 1947 the reserves were still in excess of 900 million tons, although in the meantime many hundreds of millions had been withdrawn. Similarly a competent authority in 1945 estimated the proven oil reserves of the United States at a figure more than four times as great as the accepted estimate made in 1915 in spite of the tremendous withdrawals during the generation that had intervened. Since that time the great oil fields of the Middle East have been discovered, and promising fields in other areas have been opened. Thus any attempt to estimate the real extent of world reserves of oil becomes an exercise of dubious value. Yet we cannot escape the fact that this resource is being consumed at a rate never before approached in history, and that the rate of consumption is steadily and rapidly rising.

Since the beginning of this century the depletion of our mineral resources has been proceeding at an unexampled rate. Indeed, the quantity of mineral products consumed between 1900 and 1949 far exceeds that of the whole preceding period of man's existence on earth. It is a grim commentary of human intelligence that a great proportion of the minerals used during the last five decades has been criminally wasted in the waging of the most destructive wars in history.

The increase in consumption since 1900 have covered all the more important metals and minerals. During that time production of pig iron, lead and tin has more than doubled; zinc and copper have quadrupled, aluminum, nickel, tungsten and others have shown still greater ratios in increase.[1] A similar expansion has occurred in the use of industrial minerals, while the use of certain metals used in alloys has risen to astronomical heights.

The rate of consumption of any mineral resource is, of course, subject to a variety of influences. Under conditions of free enterprise mineral deposits are normally exploited only when the margin between the costs of production and the price the consumer will pay will yield a profit to the operator. Obviously, therefore, any improvements in mining, milling or refining techniques that result in lower production costs or in an increase in the percentage of the metal recovered, will correspondingly increase the total of our commercially available resources. The more efficient we become in the utilization of low-grade ores, the more satisfactory our supply position. The same result can also be obtained in the free market when the consumer is willing or able to pay increased prices. It is only in times of emergency, and unfortunately this usually means in

---

1 Under present conditions something over 100 million tons of pig iron, about 3 million tons of copper, 2 million tons of aluminum and 1¼ million tons each of lead and zinc are annually required. (This does not include the large and growing consumption of scrap metals.)

times of war, that the influence of prices becomes insignificant. In such circumstances scientific or technical considerations rather than market influences decide the availability of essential commodities. Finally, the supply position is affected by the accessibility of deposits, the availability of labour and power, and such political factors as taxation and royalties.

Significant as these economic factors are, however, they do not affect the over-all position of the extent and variety of our mineral resources - except as they may advance or retard the current rates of consumption.

It is significant that in the cases of agriculture, forestry, fisheries and certain other fields of resource development some progress has been made in the direction of conservation. All these are renewable resources. Yet in the case of minerals, which are not renewable, there has been practically no effort, except in time of war, to interfere with the free play of a market that is interested only in profits. This anomaly cannot continue indefinitely.

IV

If we cannot give an adequate estimate of our present resources we may find some significance in an examination of the certain trend of future demands. If these should, in any instances, expand beyond all likelihood of any comparable new discoveries, that fact will be immediately pertinent to our inquiry.

There are certain basic factors which are clearly distinguishable. The first of these is the rapidity with which the number of human beings on the earth is increasing. Success in the battle against famine and disease is contributing directly to this result. Not only is the population increasing, it is increasing at an accelerating rate. At the present tempo the population of the world will double in less than 90 years. The current increase is approximately 20,000,000 persons per annum or about 60,000 every day. Even in the length of time occupied in the presentation of this paper over 1,500 more human beings will be born than will have died. In military terms, two new battalions are added to the population of the world every hour of every day.

A second fundamental factor is found in the almost universal demand for a higher standard of living. This will mean, inevitably, an expansion of the demand for mineral products.

As an indication of how this might affect the world's mineral resources, a distinguished American scientist recently prepared a study of the consumption of pig iron in the United States as compared with that in the rest of the world. In 1945 the utilization in the United States was 790 pounds per capita; for the whole world, including the United States, it was 97 pounds; for the world, not including the United States, it was 47 pounds. He then went on to say that these figures deserve careful thought by those who envisage supplies for the whole world even remotely approaching those of the present highly industrialized countries.[1]

Consider what would happen if the rate of consumption of iron were to rise throughout the rest of the world to one-half

---

1 Sampson, Edward. "Some Aspects of Mineral Adequacy". Paper presented at the Annual Meeting, Canadian Institute of Mining and Metallurgy, Montreal, April 1949.

the present rate in the U.S. The total demand - on the basis of the present world population - would be in the neighbourhood of 450,000,000 metric tons per annum. Applying the U.S. experience on the same basis to other metals it is possible to envisage a prospective world demand for

10.9 million metric tons of copper
8.7 million metric tons of aluminum
8.3 million metric tons of lead
6.8 million metric tons of zinc
2480.0 million metric tons of oil

But the population of the world will not remain static and there is no reason to believe that the people of other nations will be satisfied indefinitely with a rate of consumption only one half that of the U.S. to-day. Yet if demand in these proportions should develop, it would, so far as we now can estimate, be greatly beyond the capacity of any known or probable supply.

Increasing scientific knowledge combined with humanity's desire for a decent standard of living, have resulted in the development of many new uses, not only for the common metals, but for those less known and more rare. Among the latter attention is now being centred on uranium as a source of atomic energy but there are also cadmium, calcium, columbium, magnesium, molybdenum, tantalum and titanium. The last of these is still in its experimental stage of production but it possesses such inherent physical qualities as to capture the imagination of metallurgist and manufacturer alike, being as strong as steel with half the weight and with great resistance to corrosion.

Many of the new advances in man's mastery over nature place additional burdens on our metal resources. Air and automotive transportation, electrical refrigeration, air conditioning, radio, television, and rural electrification are all developments which have greatly expanded the demand for metals. The utilization of atomic energy will require vast increases in the production of steel, copper, lead and the rarer metals.

Within the last two decades the metallurgist has sought to improve the quality of metals for manufacturing purposes by the addition of alloying elements to obtain greater strength and other desirable properties. To-day these alloys are virtually made to the order of the manufacturer and designing engineer. As the research metallurgist gains more and more knowledge of the properties of metals, new combinations of properties will be provided by alloys of the future, each one serving some particular need of industry. As this science proceeds the demands for the rarer metals will correspondingly increase. It is here that critical shortages may first appear. For example, in the development of metal alloys to withstand the high temperatures of the jet engine, columbium and cobalt are regarded as essential. Yet these metals are not only rare in the composition of the earth's crust but economic concentrations are exceptionally difficult to find.

Thus it is quite clear that the combination of an increasing population and rising standards of living will place a strain on our metal resources which will almost certainly in the end prove beyond the capacity of man and nature to supply. It remains to be considered what steps can and should be taken in an effort to prepare for this development.

V

Our hopes for the future should be directed first towards the discovery of new ore bodies.

It has been said with a great deal of truth that the easy mineral finds have now been made. A review of the discoveries made within the last two decades, particularly in the base metals, reveals only a few of major importance. With minor exceptions the metals are to-day coming from areas that were discovered many years ago. Only the intensive work of the geologist and mining engineer in determining the structure and extension of the known ore bodies has lengthened the active life of these mining areas. Other ore bodies buried beneath glacial or other overburden undoubtedly exist but their discovery can seldom be accomplished by surface prospecting. The lonely prospector with hammer or pan is to-day a romantic rather than a significant figure. In his place the contribution of the scientist must be brought to the rescue of the mining industry.

Already much has been done by the physicist and geologist in the use of geophysical methods of prospecting for oil concentrations. The use of the magnetometer, the dip needle and other similar devices is beginning to reveal mineral deposits hidden beneath the overburden, although their results must still be checked by physical means such as diamond drilling.

Probably the outstanding development in geophysical prospecting in recent years has been the airborne magnetometer. By this means a continuous record can be made of the magnetic intensity along the path flown by the plane. This record enables the geologist to determine areas of high intensity such as are usually associated with metallic ore bodies. The results obtained are generally as accurate as those obtained on the ground and the flying magnetometer has the advantage of speed since one hundred and fifty miles or more of magnetic profile can be secured in an hour of flying time.

Other scientific aids in prospecting for certain ores include ultra violet light, and recently in the search for radioactive materials the Geiger counter has become indispensable.

The greatest hope for fresh supplies of ore depends upon the discovery of new ore bodies in those areas as yet undeveloped. The map of the world shows vast areas of South America, Africa, Northern Canada, Asia and Australia, which have not yet been geologically mapped or intensively prospected. New deposits will certainly be difficult to find but with our constantly growing knowledge of the geological and allied sciences it may reasonably be expected that many discoveries will yet be made.

VI

The second step to be taken in our effort to postpone the inevitable date when mineral shortages will develop is the improvement of our techniques of extraction and processing. New and more efficient methods of mining are constantly being sought. In addition, we must continue to broaden the field of research in our metallurgical practices. The record of discovery in this field offers good evidence that further research will result in further refinements. The development of the cyanide process made it possible to recover gold from ores previously regarded as worthless and thus added immeasurably to the world's reserves of this metal. The change from gravity methods of concentration to froth flotation produced comparable results in the treatment of sulphide ores. The electrolytic refining of metals has not only increased the purity of the product but has been responsible for the recovery of many new and rare metals as by-products. Cobalt and metals of the platinum group are recovered from the copper-nickel ores of the Sudbury area, while cadmium, bismuth, indium, thallium and other rare metals have been recovered from lead-zinc refineries. The introduction of dust precipitators and baghouses into the smoke stacks of smelters and roasters has resulted in the reclaiming of large quantities of metals that have been volatilized or vapourized. The development of processes for the manufacture of sulphuric acid from the smelter gases resulting from the treatment of sulphide ores is now established practice. A large part of the world's requirements of magnesium and magnesia are now extracted from sea water, a procedure that was considered fantastic when it was first proposed less than 50 years ago.

These are merely examples of past achievement in a field in which further progress can be confidently anticipated. In the future, as higher grades of ore are depleted, more attention must be given to the treatment of complex and low-grade ore bodies by leaching or other chemical methods. Further study must also be given to the possibility of obtaining minerals from sea water.

In addition to the search for new ore bodies and the improvement of our processes of extraction and treatment, greater study must be given to the possibilities of conservation and substitution.

Under the heading of conservation there are two steps of obvious importance. The first is the re-use of metal scrap. Among the more highly industrialized countries scrap to-day plays a role of real and increasing importance. The chief sources of supply are the obsolescence of manufactured metal products and the waste that results from machining and other steps in fabrication. In the latter case careful segregation and handling of the waste permits its direct return to the melting furnaces. Waiting for metal products to become obsolete is a slower process but in those countries that have long been industrialized the supplies of obsolescent or obsolete material are playing a more and more important part as a continuing source of metal reserves. In typical recent years scrap provided 49% of the iron, 42% of the lead, 34% of the copper, and 13% of the zinc used in the United States.

The second step in conservation is the prevention of corrosion by the use of preventive coatings of some other metal or of one of the resin compounds, or by the creation of new alloys that resist the corrosive influence of the elements. Much work has already been done in this field but much more remains to be achieved.

Closely related to conservation is substitution, and substitution is being achieved in a rapidly increasing variety of forms and instances. Technical developments in manufacturing often permit the substitution of metals that are in plentiful supply for others that are relatively scarce. The use of aluminum and magnesium in transportation and other fields as a substitute for steel is an example of this process. These metals and their alloys have also been applied to many structural and building uses in which strength is not of paramount importance. The use of aluminum as a substitute for copper in electrical transmission lines has effected a tremendous saving of the scarcer metal. Where lightness is a factor in design, both aluminum and magnesium are being used with marked success in the castings industry. The knowledge and skill of the metallurgist are now being devoted to the introduction of new alloys of these metals that will further widen their use. The supplies of both are relatively abundant.

The short supply of tin and its comparatively high price during and since the war have led to reductions in its use and in some cases to substitution in alloys, babbits and solders.

Perhaps the most important developments in the field of substitution are those provided by the industrial chemists who have produced synthetic products that can be used in place of metals in an increasing range of manufactured products. So extensive and successful have these developments been that an increasing number of chemists are prepared to argue that prospective shortages in the field of metals can be disregarded. They cite the case of the nitrate fertilizer industry and the plastics industry as examples of the alchemy of the future.

In a book written by the Chief of the Forest Products Branch of the Food and Agriculture Organization of the United Nations, and significantly entitled "The Coming Age of Wood",[1] the author argues that the material salvation of the world is to be found in a properly managed forest policy. According to his argument wood can supply not only hamburg steaks and fur coats but, suitably treated, can also take the place of metal for almost every purpose in which the latter is now used.

Without accepting all of the claims of the chemical fraternity, it is undoubtedly true that over a very wide range of use synthetics can be employed to relieve the pressure on our mineral resources. It must, however, be recognized that chemicals, which in turn are based on inorganic materials, are employed in the manufacture of those synthetic products, Thus, indirectly, the drain on the mineral resources of the world will continue even though it may be reduced by the use of synthetics. Moreover, it is probable that there will always be certain cases in which the requirement of high resistance to shock and other similar specifications will demand the continued use of metal products. Given the type of civilization that humanity has developed and that is likely to characterize the future of the race, the demand for metals to be used in circumstances of this kind will certainly continue. Consequently, the use of plastics and other similar synthetic products should now be regarded as an important conservation measure; we can only hope that it will eventually develop into a final substitute.

In this connection, however, it should be recognized that considerable progress has been made in the devising of synthetic mineral products. Prior to the first world war Chile was virtually the only source of nitrate for fertilizers and explosives. The development of a process for the manufacture of synthetic sodium nitrate and ammonium nitrate has reduced the world's dependence upon the natural product, although it is significant that the production of natural nitrate has not appreciably declined. Artificial crystals, artifical mica and artificial graphite have all been successfully produced and for some uses are even considered to be superior to the natural product. Perhaps the outstanding development in this field has been the manufacture of the artificial abrasives, silicon carbide and carborundum. These have largely replaced the natural abrasives, corundum and emery, economic deposits of which are relatively rare. Fortunately, the mineral basis of these artificial substitutes, silica, alumina and coke, are in abundant

---

1 Glesinger, "The Coming Age of Wood". N.Y. 1949.

supply. A further example of this kind of substitution is to be found in the development of an artificial cryolite from the use of fluorspar thus reducing the importance of the natural cryolite upon which the aluminum refining industry depended, and which is known to exist only at Ivigtut in Greenland.

VII

In conclusion we must revert to the theme that has been fundamental to this whole discussion and repeat again that our knowledge of the world's supply of mineral products is so meagre and so unreliable as to make it impossible to forecast with any assurance even an approximate date at which we will be faced with a critical shortage of any specific item. It is clear, as I have already stated, that there is no serious and immediate over-all and irreplaceable shortage of any essential mineral. But it is equally clear that the demand for mineral products is increasing at such a rate that unless there is a fundamental change in the economic fabric of human society we will ultimately be faced with the exhaustion of many of our mineral reserves. In some cases, particularly lead, cobalt and copper, and probably also iron and oil, the supply will be exhausted more rapidly than in others. New discoveries, improved methods of extraction and processing, and careful conservation will postpone the advent of critical mineral shortages. Substitution may provide alternate solutions. When shortages do develop, they may not be critical because alternatives may be available. But this is a hope not a promise. In the meantime the practices which have used or squandered our mineral resources in the past still continue and consumption is rising at a rate that can only be described as alarming.

The situation that is thus developed will make heavy demands on human intelligence and good will. Since no one nation has been endowed with all its mineral requirements, the problem crosses every national boundary. The discovery of solutions is a matter of universal concern.

The experience of the two world wars has shown the folly of wasting our irreplaceable mineral supplies in barren struggles that, apart entirely from the moral and social degradation which they produce, end only in general impoverishment and the permanent depletion of our resources. Further conflicts of this kind will hasten the day when real shortages in our reserves will develop. They may leave us too little time.

Because the problem is a world problem, the search for solutions should be on a world basis. That search can be made infinitely more productive if it is based on an increased appreciation of the necessity for scientific research in this field. There must be co-operation in the exchange of technical and industrial knowledge. Above all, there must be peace. Given these conditions we can refuse to admit that any material problem is beyond the ultimate competence of mankind.

If, on the contrary, we hold firm to our idealogical, national and racial rivalries and hatreds, if we place on our scientists the bitter burden of the prostitution of their services in war, if we fail to realize the danger as well as the immorality of the irresponsible behaviour that has marked the past conduct of international affairs, humanity will suffer the fate that it has long invited.

The world has entered a new era. Humanity has at last achieved the power of self-destruction. Our record gives no assurance that it will not be used.

Surely the time has come to abandon the perversity of war; to devote our talents and our wills to the immensely harder tasks of peace.

If we in this generation are to make our contribution to the solution of the real problem facing mankind, we must be prepared to abandon many customary ways. Our link in the growing chain that binds nature to man's needs must be truly welded if those that follow are to meet the problems of their day. It was never more true than it is to-day that

"New times demand new measures and new men,
The World advances, and in time outgrows
The law that in our fathers' day were best;
And doubtless, after us some better scheme
Will be shaped out by wiser men than we,
Made wiser by the steady growth of truth."

S/G
