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A CLASSIFICATION OF NATURAL RESOURCES[1]

ALONG with the new vogue of Malthusian doctrine there is a marked renewal of interest in the duration of certain natural resources. Research and discussion along this line are bound to be increasingly detailed and searching. One of the prime needs is a workable classification of resources so that issues will not be confused by the grouping together of items which should receive diverse treatment. The primary object of this paper is to distinguish the major divisions in such a classification. There follow some reflections on the outlook for human society in a fully populated world with diminishing resources. The probable effect of these conditions on international relations is then briefly considered.

Natural resources should be considered in at least four primary classes, two of which are exhaustible and two inexhaustible. Let us, for convenience, designate these classes by the four letters, A, B, C and D.

(A) Materials and sources of power which exist in superabundance for all foreseeable time, such as common salt, brick clay, sunlight and nitrogen.

(B) Resources permanent in their nature but limited in amount, like soil and water power.

(C) Resources that are reproduced in crops, renewing themselves regularly and permanently if not exterminated, *e.g.*, fish, forests and various animals.

(D) Limited accumulations not replenished at an appreciable rate. When gone, they are gone forever. Here belong important mineral resources, particularly coal and most of the ores.

As resources are classified here, the problem is different for each class. The duty before us is not the same for any two classes. There was an old style of thrift which taught people merely to save. "A penny saved is a penny earned." But sometimes a penny saved is a penny lost.

Class A, unlimited and inexhaustible resources, tempts the inventor, but is often forgotten by the conservationist. To develop these to the utmost is a duty. Directly or indirectly their use relieves pressure elsewhere.

Nitrogen is the best example of such a resource. Its compounds are all soluble or otherwise unstable, and hence, though incessantly produced in great quan-

[1] Address of the vice-president and chairman of Section E—Geology and Geography—American Association for the Advancement of Science, Washington, December, 1924.

tities by organic means, they have small chance to accumulate. Only in deserts have moderate stores accumulated. At the current rate of consumption the nitrates of the Andes might last for something more than a century, but agriculture should be using vastly more than it does.

The story of nitrate manufacture by drawing on the atmospheric supply need not be recounted, but some may be interested in the arithmetic of the problem. In 1918 when the United States government was manufacturing nitrate at Mussel Shoals, a body of local citizens prepared a protest, setting forth that the atmosphere of the county was being depleted and pointing to sundry phenomena as proof. This led to a simple calculation which showed that one cubic mile of air at sea level contains about twice the nitrogen now being withdrawn annually by fixation plants. The world's entire atmosphere contains six billion times as much. Moreover, all withdrawals are quickly restored by the decomposition of the compounds. So the world's supply of ciphers would scarcely suffice to write the decimal which would express the depletion of the atmosphere by all the fixation plants that the world could use.

But nitrogen alone will make neither fertilizer nor gunpowder. It must be stored in nitrates. If the compound be of potash or soda we are again limited by the base employed, to say nothing of the energy consumed in the manufacture. It is true that nitrate of ammonia contains no ingredient that is exhaustible, but even so we must not forget the power used in its manufacture, and its use is largely confined to explosives. It should be stated clearly that there is probably no inexhaustible substance on earth whose availability in civilized life is not limited by something else.

It is worth noting that the superabundant supply of nitrogen is now tapped in another way, that is, by the way of nitrogen-fixing bacteria. This double success with nitrogen is so spectacular as to be in danger of fostering vain hopes concerning other substances. But it must be remembered that the world's stock of nitrogen is not in compounds. It is at least free to make engagements, though not very anxious or even willing to do so. With most other substances a divorce is necessary before a new attachment can be made.

Building materials afford an impressive contrast between exhaustible and inexhaustible resources. Wood will be mentioned under another class. It is enough to say here that as a primary building material it belongs to the past and not to the future. Stone and common clays are inexhaustible; perhaps also cement materials. We are changing slowly, but why so slow? Those who think in terms of styles and markets, supply and demand, may find the reasons adequate, but to the man who thinks in terms of an ordered world and of the future, the change from wood to mineral substances is absurdly slow. In the nature of the case the latter are inexhaustible. These artificial portions of the earth's crust which we call brick and stone houses are only rearrangements of the crustal materials and it is hard to see how they need become impossible so long as there is a crust left to live on.

It would not be easy to add other illustrations of equal importance in Class A. The list now is much the same as it was 20 years ago, though production has in the meantime been facilitated. Hopes were excited then as now of illimitable potash to be taken from the sea or from felspathic rocks, of aluminum from the silicates, of the power to be derived from tides, from the sun's rays, and from the earth's internal heat. Science is still standing in a reverie before these problems as it stood before most of them twenty years ago and twenty years before that. A similar illustration, not known twenty years ago, but much spoken of these days, is found in the internal energy of the atom. No one knows as yet whether, even theoretically, the amount of energy afforded by a disrupted atom would be greater than the amount needed to disrupt it.

All these examples are matters of common knowledge. They give some idea of the nature of the problems in Class A and of the immense significance of making such resources available. They show also the precarious nature of the world's hope in so far as it rests on discoveries not yet made. The public to-day has a childish faith that science will discover something. When confronted with the elementary facts about the waste of resources, the unthinking man consoles himself with "Oh, science will discover something." The less a man knows of the conservation of energy, the more satisfying this faith is. Some of us call it optimism, some faith, some superstition, and some plain ignorance. There is an optimism that elevates and there is an optimism that degrades and leads to ruin.

Turning from superabundant things, we come to those which, while inexhaustible, are limited in amount, that amount being small enough to insure their complete appropriation. Two outstanding examples are important beyond all others. There are soil and water power. There will always be soil, but the supply will never again equal the demand. It may be wasted, but not wholly destroyed. Whether conserved or wasted, improved or impoverished, it will limit the world's population and the pressure of the bands will cause suffering.

The significance of water power is set forth by

linking it, and it only, with the soil, the two forming almost a class by themselves. Civilization depends almost as much on power as on food. So far as science can forecast, water is to be the great dependable source of power when the fuels are exhausted. These two great resources, soil for food, and water for power, are alike indestructible and limited in amount. The problems which they create differ categorically from those of destructible materials on the one hand and of unlimited supplies on the other. The significant point respecting Class B is its ownership. It is not so much a question of saving as of social organization. These resources of Class B form the only basis for enduring monopoly and a permanent privileged or "noble" class. The superabundant materials of Class A can not, of course, be monopolized, and any monopoly based on exhaustible supplies will come to an end with the exhaustion of its basis. All orders of nobility in the past have been based on the soil, yet in the worst nobility-ridden country on earth the property basis of a privileged class has never been better than that which is afforded by water power in half a dozen leading nations. A family that owns a Niagara need only *sit tight* like an English lord. But even sitting tight will not insure a permanent income from an oil or steel monopoly.

Our Conservation Commission computed nearly twenty years ago that when the water powers of the United States are developed to their fullest capacity, assuming all possible storage and the use of power not available throughout the whole year, the grand total will rise to 200 million horse power with a rental value of 4 billion dollars a year (at twenty dollars per horse power per year) and a capital value of 100 billion dollars. This is vastly greater than the value of all our farm lands. The latter will, of course, increase greatly in value; but the assumed value of the former is based on the continuance of coal. What will be the value of the waters when the coal is gone?

The problems of irrigation have much in common with those of power, but the uses of water for navigation and municipal supplies are government functions and the problems which they present are of a different nature.

The facts here presented are old, yet the nature of the problem is not commonly perceived. Emphasis is here placed on the fact that there are only two resources of the first magnitude which are inexhaustible and yet limited; that one of these has afforded the basis of all orders of nobility in the past and that the rights to the other are now being determined. Twenty years ago it was among the possibilities that this vast estate, many times greater than all that William the Conqueror gave to his retainers, would be used to establish a permanently endowed class in America.

In the treatment of this Class B it is a pleasure to record progress since the Conservation Commission did its work. At that time the federal government had just asserted its right to charge a rental for power developed at dams built by the government itself to improve navigation. No right was yet asserted and vindicated to make a similar charge when a company was granted the privilege of building its own dam for power purposes. It was not until the federal power act was passed in 1920 that the United States made clear announcement of its intention to treat the water power of navigable streams as the property of all the people. It is now clear that the power of streams over which the federal government has control will be leased for terms not exceeding 50 years. As for state policies, some states were in advance of the United States and others are more backward. As late as 1909 New York granted perpetual franchises practically without charge (25 cents per horse power per year).

Class C comprises exhaustible resources which are, however, continuously reproduced at a slow rate unless exterminated. To think of these in terms of Class A, or Class B, and to treat them accordingly would be to miss the point entirely and to confuse the issue. The foremost member of this class is forests, one of the first items which stimulated the conservation movement. In the same class with forests we must consider fisheries of all kinds and all animals which are taken as game or captured, like elephants, to be domesticated. The elephant is a noble race and serves man well, but he breeds poorly in captivity and the rate at which the wild stock is drawn upon may exterminate the race in 100 years (Williston). What would the Indian or the Siamese say to such a forecast? A man not blinded by self-interest or by "business principles" would probably say: "Find out at once as nearly as possible how many wild elephants are born in a year and limit killing and capture accordingly. If life and business in tropical Asia are so organized as to use up more than the annual crop, then reorganize life and business at once, instead of letting them go to smash later." It would be pleasant to hear a business man give that answer instead of saying: "That's all right, but it's not business. I'm not in business for my health. The elephant will last as long as I do."

Returning to the more familiar illustration of forests, it would be a pleasure to record that the agitation in President Roosevelt's time resulted in changing the practice. Our forests then covered 550 million acres; they now cover 470 million acres. They

were then growing annually 7 billion cubic feet of wood and we were taking from them 23 billion. The latest figures show a slightly increased use and a reduction of annual growth from 7 billion to 6 billion cubic feet. These figures afford little hope that wise practice begun in time may avoid actual hardship. Meantime wood is rapidly becoming a semi-precious substance.

There should be no questions about America's future supply of wood. There is more than room for all necessary forests when every acre of good agricultural land is in crops and all the good pasture land is in grass. We can balance our annual wood account in either of two ways. Our annual increment of growth instead of being 6 billion cubic feet may be more than doubled by mere care along old lines of practice, and more than quadrupled by forestry methods which are a century old in Europe. This alone would balance our account. Or, if we prefer, we may reduce consumption. In prewar days the per capita use of wood in Germany was one seventh of ours. In France it was one tenth, and in Great Britain not much more than one twentieth. Substitute materials in all cases come largely from what we have designated Class A, unlimited and inexhaustible resources. Of course, no one asks that our use of wood shall be reduced to a European basis, nor is it necessary. But the sensible thing to do would be to slow down when we see the wall ahead and not come up against it with a crash.

The problems of Class C require no higher mathematics. Arithmetic and common sense are the only prerequisites. It is almost irrelevant to talk about research if we mean to make it a substitute for common sense.

The facts about Class D are always disquieting. It is given to every thoughtful man to be shocked at least once when he first realizes that some very common and supposedly necessary substances have not long to last. It requires a good imagination to visualize life even in the 21st century. Of course, coal will still be with us, unless the present geometrical progression in the rate of usage should continue, which no one expects. On the other hand, no one expects the rate to remain fixed. The world has still to double in population and most of this increase will be in the white race which is the coal-using race. It is small satisfaction to know that we have 2,000 years' coal supply if used at the present rate. Probably no statistician would compute that the rate will not be doubled again, and more than likely at least twice. At any rate we have ahead of us a small fraction of the Christian era before this basic condition of life will be so changed that imagination fails to draw the picture. Long before its exhaustion the price of coal will be what we would now call ruinous. At the same time greatly increased quantities will be needed to extract the diminishing metals from what we would not now call ore, but wall rock or country rock.

Iron is among the most abundant elements of the earth's crust. As a precious or even semi-precious metal it can never be exhausted. But as a base metal the supply depends on a degree of concentration which occurs only in isolated bodies which we call ore. It is not to be supposed that all the great iron ore deposits of the world are known, but even making fair allowance for new discoveries, as well as for increased usage, it would take a brave statistician to promise more than a century of iron at prices which would belong in the present class.

Copper belongs with cheap iron and some other things of which it may be said: There is no certainty of a century, but even if the time be two centuries the moral would be the same. In any case the cost in terms of human labor will be greatly increased. If water power is to have the importance predicted, copper for electrical appliances will apparently be almost a necessary factor in civilization.

It is unnecessary here to enter upon a calculation of the constantly growing stock on hand of all the metals. The proportion actually used up and lost is constantly decreasing. None the less, the growing use far outruns the accumulation and the metals are being mined at ever increasing rates. There is no reason to hope that accumulation will ever be so great as to prevent an unprecedented rise in price at the first indication of final failure of the mines.

The mention of increased cost is about equivalent to saying that an increased proportion of human time and effort must be given to earning the metals to keep a mechanical civilization going. One might receive this statement with equanimity if he had not just been told that an increased proportion of his future time and effort must be given to food-getting. Probably no one questions these obvious assertions except to waive them in favor of those uncertain scientific discoveries with regard to which the public is so confident and scientific men so cautious. The argument that an increased proportion of human effort must be given to producing wool and cotton for clothing is quite as convincing even if less direct.

One begins to wonder what will be left of human life after all these baser but necessary functions have exacted their increases of time and effort. Could there be any mistake in the reasoning? The reasoning is right. Human wants are supplied partly by labor and partly by mere *bonus* of nature. Labor merely supplements the bonus. As the bonus goes up or down, labor goes down or up. In certain con-

ditions of life bananas are almost a pure bonus. Fish may be approximately so when sufficiently abundant. With fertile soil and small population, the bonus element is large. With depleting soil and increasing population the labor element increases constantly.

It is unnecessary to formulate the corresponding statement for coal and metals. The application is obvious. Perhaps the most spectacular bonus ever given to the race was natural gas and liquid oil. The equivalent in labor would have been beyond computation. The complete expenditure of America's share of this bonus is so close at hand as to be sensational. The rest will follow in a few years; then comes the painful effort to get the same value from oil shales, in which case the bonus element is smaller and the labor element is larger.

This line of reasoning would not lead us to a leisured or leisurely world. Natural resources are simply nature's bonuses. Half of them are expendable and very temporary. Most of the rest are limited in amount and constantly being divided up among more and more people. Aside from the depleting of some soils the expending process scarcely began before the middle of the nineteenth century. Some of these bonuses are now nearly spent, and the race is preparing, as it were, to go back to work. Others will be spent within this century. In most if not all cases the necessary labor to supplement nature's gift and make it available will be distinctly greater in 100 years from now.

There is a superficial way of reasoning about the future by analogies with the recent past, oblivious of diminishing returns, heedless of the calculus of curves and even of simple arithmetical sums. Such mental processes may lead to visions of indefinite development of our present mechanical civilization, always with growing wealth and luxury and always with increasing foreign commerce. The picture generally includes an orgy of science and invention which liberates unlimited stores of everything the race may need or wish for.

The future outcome of science and invention is, of course, unknown. As for the known factors in the above forecast, they warrant no such picture. A stronger case may be made out for the attainment of a maximum rate of advance to be followed by a gradual slowing down; a maximum degree of complexity in our civilization to be followed by returning simplicity. So far as can be seen the use of mechanical energy (now mainly from coal) will follow such a course. The use of all metals will follow the same course, the cost of iron in a few centuries becoming similar to that of copper or lead to-day. It would seem that an increasing portion of human life must be given to the mere wresting of food from a limited soil for a greatly increased population. What with the low cost of human beings and the high cost of machinery it would not be surprising to see much machine work revert to simpler methods.

Increased efficiency in labor, in machinery and in organization would retard rather than prevent the changes which are here forecast. Revolutionary discoveries may be made, but for the present these are speculative factors and do not enter into the calculation.

It does not follow that the diminished vitality of material civilization should involve a loss of intellectual life. It might even be that for a time great intellectual energies might be turned into new directions. Still, so mundane is our nature that periods of the world's greatest intellectual activity have generally been associated in some way with material expansion, and the first assumption would be that the present intellectual blaze is in a way dependent on the recent opening up of the rich coffers to which the key has just been found. It is, of course, conceivable that the momentum of intellectual activity may be such as to carry on a material civilization into constantly new fields by constant new discoveries to take the place of exhausted resources. This is what the optimist looks for with a credulity that he would ridicule in religion.

Any forecast based on known factors would probably provide for the burning out of the fires of our complex mechanical civilization, supported as it is by stored up and exhaustible resources, and after that again the simple life, not in detail like that of our fathers, but less complex and distracting than our own. According to his temperament the observer may look for a subsidence of the intellectual level or for a great blooming and fruiting in the realm of mind. In any case we are in the midst of a great experience; spending a bonus which the race overlooked for half a million years and which can not last half a thousand.

The relation of natural resources to national interests and international relations is a phase of the question which greatly interests us at present. All questions about national concerns lead into the one great question of peace and war. The idea is gaining much currency that as the world fills up and its remaining resources are appropriated or used up, the scramble for what is left will become progressively fiercer and wars more common. This seems to us plausible rather than convincing. A proper classification of natural resources ought to aid clear thinking on such a question.

The superabundant resources of Class A ought scarcely to cause trouble among nations. The same

is true of Class C, resources reproducible by crops. It is, of course, conceivable that issues should arise over forests or over the right to fish in certain waters, both of which have caused trouble in the past, but these are scarcely of the order contemplated in the alarming forecast referred to above. Sharp national issues arise over resources of Class B and Class D.

The great resources in Class B are soil and water power. Wars have been fought over the former and may yet be fought over the latter. The soil problem and the food problem are inseparable. Migration of peoples, always accompanied by wars, have been ascribed more largely to the food motive than to any other. There was a time when there was no other way of shifting from an overpopulated area to one where the soil could support more people. More recently emigration from country to country has been a personal and peaceful matter. With such a method general, a fluid population would move peacefully like currents of air from places of greater pressure to places of less until the pressure is equalized. Against this peaceful flow, barriers are beginning to be erected and it is not improbable that these will be multiplied as the world fills up. It is conceivable that we may come again to the condition in which migrations must be military if made at all. In other words, immigration questions are related to the larger question of the soil and may conceivably cause national conflicts.

It is not easy to point to an international crisis in modern history in which the acquisition of soil for food purposes was a major consideration. An admixture of economic motives in most if not all wars is now recognized by every one. Disputes about trading rights have been among the commonest causes of war. But fighting for trade must not be confused with fighting for life or for the necessary food to support life. The two are about as much alike as the scramble to get rich is like hunting for a job. All the wars for trade in all history afford no precedent for what is being depicted as a final life and death struggle for soil to grow food on.

Admittedly such a struggle would have to be for an area not fully peopled, as no one has yet assumed the extermination of a people for the purpose of appropriating its food supply. This almost limits the problem to the current century, as no one seems to expect that any country after that will be less than fully farmed. There will, however, still be differences in the pressure against their several capacities, the logical results of these differences being emigration and trade. Issues, therefore, will be much less apt to concern the political title to this or that area than the right to emigrate and the right to buy. Both of these questions need study from the world standpoint. But the broad assumption of a wholesale war scramble for food lands seems to be snap judgment. It may even be worth pointing out that the overpopulated and underfed countries of the world are not now aggressive. India and China are not feared. The one country which was the bugbear of Europe for several generations is the one which has the greatest area of fertile soil. A hungry man may fight for food so long as he remembers what a good meal tastes like. But national hunger comes on slowly and it remains to be demonstrated that a nation long underfed is dangerous.

The resources of Class D are undeniably bones of contention. They are for the most part minerals; largely basic materials used in manufactures. Any one of them may hold the key to a national industry. A substance not found in the home country may be needed with terrible urgency. Yet some one may be guarding the supply. It is scarcely in human nature not to measure your wits and your strength against those of the guard.

The precious metals were the prize played for in the Spanish conquest of the new world. The gold of the Rand was the real cause of the Boer War. Without the iron ores of Lorraine there would have been no Franco-Prussian War in 1870 and probably no World War in 1914. Chile fought both Bolivia and Peru for nitrate deposits. Recently our own country came perilously near going to war with Mexico in order to "develop her resources." The petroleum situation in the world to-day is aflame with possibilities and is of the same nature as others which have brought on wars.

Most but not all attempts at forcible seizure of raw materials have been directed against the so-called backward nations. With small countries of little diplomatic standing the issue has taken the form of collecting or protecting debts, or maintaining order. In large countries poor in capital, "concessions" now break the ground in which the seeds of war and conquest may be sowed. In practically all such cases the *foreign investment* has been the first of a series of steps leading up to the use of an army on foreign soil.

There is no way of obviating foreign investments. The distribution of the world's reserves of exhaustible resources is startlingly different from the distribution of the world's capital. The latter must move to the former. It is, therefore, among the necessities of the case that much of the world's raw material shall be brought into world's life by foreign capital. Provision for this involves some relation between the two countries. From the standpoint of peace and war this relation is the most delicate and dangerous thing that confronts the world in the next 100 years.

The capital in a country becomes saturated just as population does. Some nations are overcapitalized as others are overpopulated. When all temporary expedients are exhausted both people and capital must emigrate or die. In a world no longer colonizable it is no longer practicable for large bodies of men to move to another domain and retain their old allegiance and citizenship. This may be a real hardship. It is not pleasant for a million home-loving Germans to leave the Fatherland and not form a new and tributary Germany elsewhere, but men whom fate compels to move must play the game with fate according to the rules.

The tendency of capital to retain its old allegiance after emigration is quite as strong as the same tendency in men. The extent to which capital invested in a foreign country retains its citizenship in the home country is ill defined. It varies between two extremes. If the two countries are equally strong, or if the place of investment is in the stronger country (a very rare case) the right of that country to make its own commercial laws may be fully recognized, just as immigrants to the United States from Czecho-Slovakia expect to be tried by the laws of this country without appeal to their own. But in the more usual case, where the investment is made by citizens of a powerful country in the property of a weak country, the actual situation may reach the opposite extreme wherein the acts or wishes of the investor become, almost *ipso facto,* the acts and wishes of his government. Between these two extremes there is great uncertainty and no other question or class of questions for the next century contains so much powder or so many matches.

To a man with a wide knowledge of resources, investments and international dealings, it would be interesting to peer into the future to see what possibilities are enfolded in this question. We may hazard the assumption that resources found in advanced countries (or their colonies) where there is not only understanding of their significance but some ability to share in their development are not apt to be contested in such a way as to endanger the sovereignty of the country.

The statement may also be risked that by the end of this century the resources of backward countries will be about as well known as those of Europe are to-day, and all will be covered by claims of at least one industrial nation with surplus capital seeking investment. Some of the finds will be already exhausted. The significance of this is that the time is limited within which such issues can cause trouble. Those who wish to do so may see in these conditions the occasions of many international clashes. It is not to be assumed that clashes will be wanting, but they should be mainly in the interests of foreign investments made for the purpose of increasing wealth rather than food wars as depicted by those who look forward to a final scramble for the bare means of living. This statement must not be made too categorically, as it must be conceded that national interests, such as the food of the people and the expansion of trade, may be so closely connected as to make it impossible to ascribe a war wholly to the one or to the other.

It is not easy to set the stage for the proposed food wars, even in imagination, unless the imagination is untrammeled by facts. Undernourished nations do not wage war. Moreover, food as an element of foreign commerce is bound to diminish as the great food selling countries become fully populated. As countries fill up they also become industrialized, thus reducing the need for the manufactured imports formerly received in exchange for exported food. The gradual exhaustion of resources in Class D and their rising cost will operate still further to reduce the commerce by which they are at present assembled from the ends of the earth to be fabricated in a few countries and sent again to far-off regions in exchange for food.

The obviously economic plan for a world full of people is for the people to live as near as possible to where the food is produced, and to organize a balanced community in each era, with industrial employment for hands not needed in producing food. It is generally agreed that this tendency exists and that when it becomes dominant foreign commerce will be relatively light. A little reflection will show that wars should diminish with commerce.

There may, however, be an intermediate stage induced by the great temporary demand on foreign investments. It seems highly improbable, at least, that the industrializing of the present food-exporting countries will wait on the slow accumulation of home capital. It is more probable that a loud call for capital from the new country will be supplemented by a shove from the old country. For it must be remembered that when the countries that now feed England (for example) are eating the food at home, England becomes automatically overpopulated, perhaps to the point of disaster. The incentive for capital to move is thus intensified.

It seems wise, therefore, to make allowance in one's forecasts, for a great temporary increase in foreign investments with all their attendant risks. These, rather than food, or soil on which to raise food, would seem to furnish the immediate dangers to world peace within the coming century.

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