in favor of higher-grade, more accessible, or more profitable alternatives. There is little uncertainty with regard to the existence of substantial quantities of almost any given substance. But the uncertainty of increases substantially when one considers he mineral forms, or the associated products, and such factors as location, accessibility, and the costs of extraction and processing.

V. CREATING TECHNOLOGY TO MINIMIZE RELIANCE ON CONVENTIONAL RESOURCES

Instances are seen where advances in technology would significantly contribute to minimizing reliance on conventional raw material sources to which, because of political, geographic or physical factors, access in the future may be restricted, uncertain, unreliable or otherwise potentially inadequate.

Some observers have stated optimistically that with the advent of cheap nuclear energy, even common rocks, such as granite, would become "ore" and supply unlimited quantities of all metals needed by industry. And there are those who conclude that, because sea water contains virtually all the chemical elements, the oceans will at some future time become a cornucopia of metals.

I cannot embrace such optimism, even though I will admit that the solution of future mineral supply problems lies in devising a practical universal system for directly reducing any substance into its useful components at a very low cost. If this can be accomplished, our current definitions of "resources" will disappear. I am not greatly concerned, however, that we need to meddle with these definitions, at least for the remainder of this century. I say this because, as in the case of common rock as "ore," the appreciable differences in physical and chemical form of the compounds containing the low concentration of metals in these rocks would require a vastly new and complex technology to extract them. Consider also the huge quantities of unusable waste that would be generated for each unit of metal.

Nevertheless, the existence of these obstacles should not stand in the way of an aggressive quest for at least partial technological achievement in areas that are promising. Many common substances, low in mineral content but abundant in nature and broadly distributed, and environments not fully explored or hostile can be commercially exploited with only modest advances in established technology or with more ingenious application of known principles.

VI. STRETCHING MATERIAL SUPPLIES

We can expect, during the remainder of this century, to continue to meet our material needs in several ways: Through primary production of mineral raw materials, by recapturing secondary materials in reusable forms, and by extending the useful life spans of mineral based products, reducing dissipative uses and waste, using materials ever more efficiently throughout the production-consumption cycle.

To make meaningful progress in stretching our material supplies we must find new and better ways to minimize the need for primary materials through recycling; learn how synthesis, substitution, or conversion can reduce a drain on limited supplies or achieve greater economies; and identify more areas in which significant losses and wastes can be reduced or eliminated, or needs can be minimized, through improved constitution, fabrication, and design.

Vast tonnages of pure metals and alloys are trapped in manufactured products. Many of the ever-increasing variety of alloys that end up as scrap continue to accumulate in junk piles for lack of extractive methods to separate and reclaim the metals they contain. This problem is compounded by the fact that many of these alloys—some containing metals in critical supply—were developed to resist just such conditions as are used by the extractive metallurgist in making separations. That is, they are extremely refractory and corrosion resistant to most chemicals.

We will be able to stretch our resources much further when we can properly design systems that will extend the life of products; make easier their maintenance and repair, and/or simplify the salvage of metals. We must continue to improve our techniques of solid waste management. By this, I mean that through technology we must strive to achieve optimum recovery of all metal and mineral values during ore extraction and processing. The emphasis here is on saving the mineral values, thereby reducing the need for future retreatment of wastes. Material supplies can also be stretched by finding ways to use relatively abundant minerals, rather than relatively scarce ones, to meet our needs for a particular commodity.