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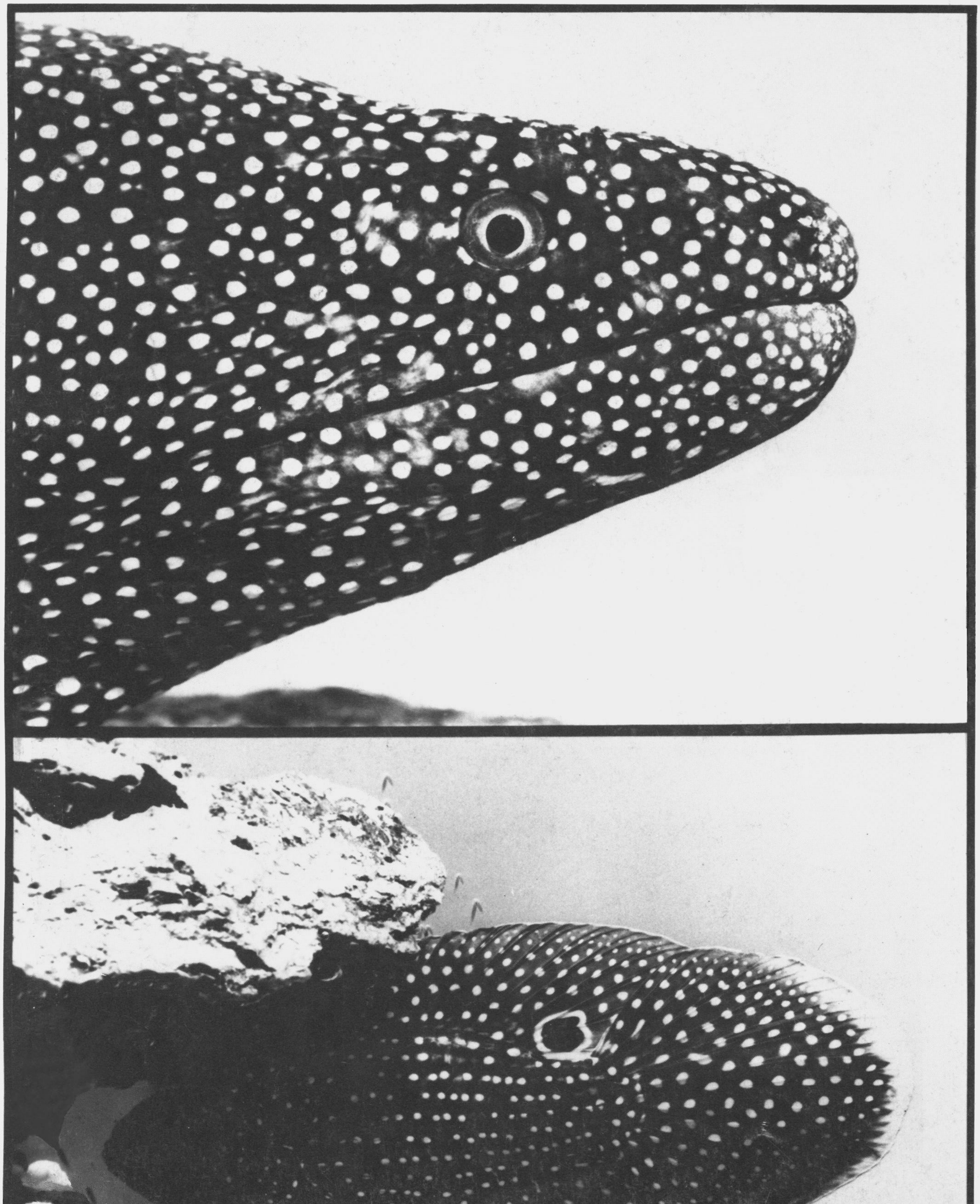

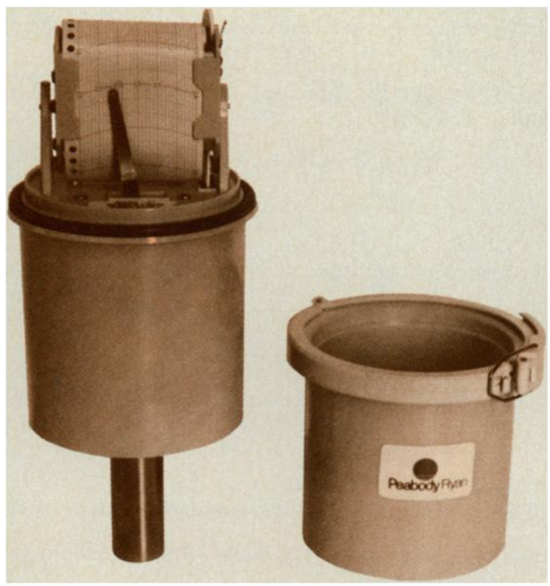

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COVER

When frightened, the plesiopid fish *Calloplesiops altivelis* adopts a posture and appearance which mimics the head of *Gymnothorax meleagris*, a noxious moray eel. The plesiopid is about 15 centimeters in length, whereas the moray eel is nearly a meter in length. See page 400 [T. McHugh/Photo Researchers, Steinhart Aquarium, San Francisco, California]

and of carbon tetrachloride into the Kanawha and Ohio rivers were discovered. However, over the years, smaller but continuous chemical discharges are not discerned by routine monitoring and are only partially revealed by their impact on fish in these rivers. Fish from the Hudson River are unsuitable for human consumption, but the Corps of Engineers recommended in March 1977 that New York City tap the Hudson for additional water supply.

While our present knowledge may not justify the great expenditures that changing our present sources of water would require, certainly we might avoid making major new investments in developing water sources of questionable quality. We need a strategy for public water supply, and such a strategy should include preserving and developing protected watersheds for water supplies that are to be used for drinking. Polluted rivers make excellent sources of water for the many nonpotable needs of an industrial society.

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Referring to the views of Stuart H. Brehm, director of the Sewage and Water Board of New Orleans, Nicholas Wade states ". . . there is no point in replacing his sand filters with carbon which . . . would interfere with chlorination . . . ." I don't think so. Carbon filtration can be employed *before* chlorination. This would enhance the disinfective efficiency of chlorination, reduce the chlorine demand, and also reduce the hazard of forming persistent chloroorganics which are of ecological concern.

If for some reason the New Orleans plant must employ chlorination before carbon filtration, there is still good reason to believe that disinfection would be satisfactory. What is encumbered is a residual level of disinfectant desired in the distribution system as a safety precaution against secondary contamination. This can be added by a secondary chlori-

nation procedure. An advantage of this system is that carbon filtration following chlorination will remove chloroorganics formed in the chlorination process as well as excess chlorine. Furthermore, in light of the ecological concern, as well as the human health concern over chlorinated organics, it is becoming fashionable again to investigate use of water supply disinfectants other than chlorine.

Finally, who has informed public utilities that average householders are not willing to pay an additional $7 per year for clean water?

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Energy and Inspiration

Philip H. Abelson's editorial "Energy conservation is not enough" (10 June, p. 1159) criticizes the National Energy Plan for not having enough "inspiration" and for providing "no basis . . . for the public to hope that America's technological capabilities will be effectively marshaled." This statement is inconsistent with the Plan as I read it. Specifically the Plan places tremendous—but realistic—dependence upon U.S. technology. Where else do we look to learn how to utilize coal resources in an effective way? Are we willing to claim that technology offers no hope of our achieving greater use of coal with less environmental impacts? Where else can we place our dependence if we are to develop much more efficient ways to utilize energy?

The great challenge offered in the National Energy Plan is to seriously commit this nation to substituting technological ingenuity for brute-force energy consumption. In the past we have overfocused on developing "gee-whiz" energy supply technologies. The Plan may bring us back a little closer to Earth, but it certainly doesn't lack for challenges to American technological leadership.

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In his editorial of 10 June, Abelson rightly points out that the National Energy Plan's "missing element is inspiration." I think we should be crasser. The missing element is financial incentive to find more fuels, to develop new technologies, and even to bring about more energy conservation.

It takes supreme confidence for the Administration to set prices by bureaucratic fiat (as would be done for oil and gas) and then declare that the supply will come forth. If it does not come forth, we will find ourselves importing more oil and liquified natural gas or gasifying coal at a far higher cost than what we would have to pay the oil and gas moguls in the Southwest. For some reason, we are asked to take our chances on handing OPEC more money than on giving Texas any incentive to find more oil and gas.

The treatment of electric utilities is another example. The Plan offers the utilities little incentive to emphasize coal and nuclear technologies because it starts out with assumptions that make the job look easy. After all, it is estimated that fuel demand by the industry will grow only 5 percent per year without the Plan and 4.4 percent with it (*1*, p.95). Furthermore, the Plan will save the industry a colossal $40 billion by 1985 if implemented (*1*, p. 97). These savings seem to be both dubious and thoroughly undocumented (*2*), and the fuel estimates seem to be no more than guesswork. But with such slow growth and huge savings on the way, the Administration provides few real financial incentives in the Plan to alter the fuel mix.

Finally, what incentives are provided to those who want to develop new energy sources, other than some tax credits that may or may not be high enough? When the price of conventional fuels is kept down exotic energy sources look less economic. For that matter, does the present research structure do the job? Can government agencies that are far from the marketplace and huge corporations that might be affected adversely by the development of new energy sources be expected to produce them? Perhaps the answer would be to create COMSAT-like private corporations to develop and market new energy devices. They would clearly have the incentive to do so, because those devices would be their only sources of income (*3*).

If we are going to have a successful energy plan we have to harness the force that made American capitalism great: old-fashioned greed.

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Last Resorts

In the 1976 presidential race, Governor Carter reportedly took the position that in solving our energy problems he would rate nuclear energy as a last resort. Some weeks ago, when the Carter Administration was found to be cutting red tape to speed the licensing of nuclear power plants, one of his retinue explained the apparent change of heart by saying, "*Now we are down to last resorts*."

Political rhetoric and rationalizations aside, this startling response gives us plenty to think about. It raises the question of how ready we are, as a people, to take the medicine that is implicit in a "last resorts" political economy. Perhaps it will not come to that, but it very well may.

Again and again, we look at the disarray in our national energy policies and at the absence of a national will to face the bleak facts. What is missing is the kind of resolution and action which marked the era of wartime mobilization, when private preferences were overridden by the common emergency. Obviously, it is futile to wish for a return of that sort of unity while we can indulge ourselves in rising imports of energy supplies and in the consolations of long-term research and development, which may help by the end of the century. The case could be quite different if the situation falls apart in five years or even ten. Perhaps an awakening to the meaning of a "last resorts" society can get us moving in the near term.

We have grown accustomed to having things turn out right, in general, and we expect it as a matter of course. To be sure, things have not gone exactly right for some groups in our society, and there is still that bill to be paid. But on the whole, our situation compares graphically with that of most of the rest of the world. In this country, especially, affluence and consumer satisfaction have brought living standards and expectations to a state for which history offers no parallel.

What can happen to the emotional and social stability of a very rich, if not spoiled, society when it is confronted suddenly with an economy of last resorts? What can become of the decency that underlies behavior in a fortunate and civilized democracy? One thinks of Western societies with which we share historical and institutional beginnings, and whose material fortunes lately have gone sour. They are already close to their last resorts, yet they seem to have come to terms with misfortune. The difference, possibly, is that these societies have 2000 years or more of cultural development behind them and are able to draw upon the perspectives and resilience that are the fruits of their embattled pasts. It is a different case with the American experience, short and one-sided as it has been.

So the question remains troubling. Is our national character prepared for a reversal of our fortunes and our optimistic expectations if events transform the good society to a condition of last resorts? Will we take the same generous view of human and economic rights, and of our relations with other peoples and races, when there is not enough to go around—much less enough to assure us the lion's share?

We are taking a lot for granted. We do not seem to believe that the American experience, as we know it, can be altered drastically and unpleasantly. We seem to think that our luck will somehow hold out, and that a worst-case future cannot materialize. We refuse to examine the social and human implications of last resorts.

That is why the present condition of policy-making in energy is so alarming, and why it may presage other policy dilemmas which will arise as global issues sharpen in the next decade. A nation reduced to last resorts is one in trouble.—WILLIAM D. CAREY

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Reports

Mining the Apollo and Amor Asteroids

Abstract. *Earth-approaching asteroids could provide raw materials for space manufacturing. For certain asteroids the total energy per unit mass for the transfer of asteroidal resources to a manufacturing site in high Earth orbit is comparable to that for lunar materials. For logistical reasons the cost may be many times less. Optical studies suggest that these asteroids have compositions corresponding to those of carbonaceous and ordinary chondrites, with some containing large quantities of iron and nickel; others are thought to contain carbon, nitrogen, and hydrogen, elements that appear to be lacking on the moon. The prospect that several new candidate asteroids will be discovered over the next few years increases the likelihood that a variety of asteroidal resource materials can be retrieved on low-energy missions.*

O'Neill (*1*) has suggested that it is possible, using existing technology, to construct large communities in a stable high Earth orbit. These communities would be built from factories that would process materials launched by an electromagnetic mass driver from the shallow gravitational potential well of the lunar surface (*2*). This concept has since been expanded to include the manufacturing of satellite solar power stations in high orbit, and offers a favorable benefit-cost ratio for the delivery of terrestrial electrical power in less than 20 years (*3*). Small asteroids have also been suggested as resource candidates because of their zero gravity fields and the possible availability of metals and other materials (*4*).

Comparing the cost of retrieving resources from competitive sources involves the study of a number of variables. Perhaps the single most important parameter is the total energy required to retrieve those resources at the most convenient opportunities. To a first approximation, the energy of retrieval is proportional to the mass and thus to the cost of the propulsion system required to move materials through the velocity increment to the locations of their end use. The energy per unit mass of resources retrieved is proportional to the square of the velocity increment, Δv, and so the evaluation of Δv for sample missions provides a useful data base for the economics of nonterrestrial mining.

Mascy and Niehoff (*5*) have outlined a mission profile for a sample return from the Amor asteroid 433 Eros. Niehoff (*6*) has evaluated the opportunities of a mission to the recently discovered Apollo asteroid 1976 AA and to the Amor asteroid 1943 (1973 EC). He concluded that a 1-kg sample could be returned to the surface of Earth in a 3-year round-trip mission to asteroid 1943 launched in 1992 by one space shuttle containing a supply of propellants and a recoverable upper stage. Other investigators (*1, 4*) have discussed bringing material in from the asteroid belt, about 2.5 astronomical units (A.U.) from the sun. Table 1 compares lunar missions with favorable missions to various asteroids, broken down in short-thrust velocity increments from low Earth orbit to a heliocentric Hohmann transfer orbit (Δv_{esc}), from transfer orbit to rendezvous with the asteroid (Δv_{rend}), from departure from the asteroid to the vicinity of Earth (Δv_{dep}), and from injection into a high Earth orbit (Δv_{heo}).

Table 1 shows that a round trip of minimum energy to a main belt asteroid of very low inclination and eccentricity would require energies (Δv^2 per unit mass) several times those for selected Apollo and Amor asteroids. The Earth-approaching asteroids become even more economical candidates than main belt asteroids when solar energy is used for transport. The main belt asteroids are in a region of solar flux five to ten times less than that at Earth, whereas the Apollo and Amor asteroids are in a region of solar flux one to three times less than that at Earth. Thus a transportation system utilizing solar energy, with a power plant subtending a fixed area exposed to sunlight, would yield five times as much energy at a selected Apollo or Amor asteroid as at a main belt asteroid. When factored in with the comparisons in the energy of transfer orbits (Table 1), it is possible to gain a factor of $\gtrsim 30$ in throughput for the transportation of material if a selected Apollo or Amor asteroid is used instead of a convenient main belt asteroid. These considerations are obviously vital in discussing initial investments in space manufacturing.

Optimized round-trip missions to some Apollo and Amor asteroids require energies comparable to those to the lunar