acquiesce now in this particular subversion of the moral principles of the scientific profession, then in the long run we may bear the responsibility for the decadence of our own science at the hands of politicians, administrators, and other gentle experts in the arts of expediency.

Much can be done by individual protests and boycotts. But the responsibility for the protection of the norms of science rests squarely on the great learned societies, led in Britain by the Royal Society. If they fail in this duty, then who else could be blamed for inaction? What has prevented the Royal Society from speaking up in defence of the scientific ethos which it is pledged to preserve?

On the one hand, there are a few leading British scientists who hold that any criticism of Russian scientific policy is a political act motivated by disreputable ideological ends. On the other hand, there are administrative 'realists' who have no illusions about the disabilities of Soviet scientists, but who insist that more can be achieved by secret diplomacy than by open comment. These two extreme parties combine to prevent the whole subject from being properly discussed. For opposite reasons they express themselves strongly against any action, and thus paralyse the large middle body who feel uneasy about the situation but who have no great personal interest in upsetting the *status quo* of acquiescence. It is to the conscience of this group that my argument is addressed.

The most important and decisive action would be public recognition by the Council of the Royal Society of the main facts concerning the state of science in the Soviet Union, and an expression of support for the basic principles of academic freedom and integrity. Whatever might be the overt reaction of the administrative organs of the Soviet Academy of Sciences, such a statement would make it quite clear to the main body of Russian scientists that we understand their present position and sympathise with their personal endeavours to contribute honestly to the world stock of human knowledge. In the absence of such a public statement, claims of influence by secret bargaining are without weight; the very fact that various officers of the Royal Society deal directly with the officials of the Soviet Academy can only suggest to other Russian scientists that they are ignorant of, acquiesce in, or even approve the corruptions with which we are here concerned.

Exchanges of Scientists

It is often suggested, both by Soviet apologists and by official 'realists', that the channels of communication must be kept open. They point, for example, to the Scientific Exchange agreements by which visits are arranged between the Soviet Union and other countries. In all honesty, however, it must be admitted that these exchanges are of such insignificant proportions that their value is negligible. The number of Russian scientists that visit Britain under such schemes is probably about the same as the number of Israeli or Australian scientists who come and talk with their British colleagues. The truth is, also, that many of the present Russian visitors to the West are of very low scientific standing, and are apparently more competent at picking up snippets of information than communicating at the highest intellectual level with our own leading scholars. The average Soviet scientist of good repute has so little expectation of making a foreign visit himself that he would not be greatly perturbed if those particular exchanges were inhibited!

In any case, the flow along these channels is controlled almost entirely by the Soviet authorities themselves. It is not suggested that the Royal Society, the British Council, or other agencies should act in any other way than to welcome exchange visits by *bona fide* scientists. If Soviet officialdom were to react to criticism of their domestic policies by refusing to collaborate in such exchanges, the responsibility would be theirs. What sort of a bargain is being struck when one promises silence in return for an agreement that mainly benefits the other party?

And that is the heart of the matter. The present efforts of the Soviet government in the scientific and intellectual sphere seem directed with pathological intensity towards suppressing all internal criticism. For all the talk of *détente*—an issue which lies of course in the political sphere and therefore outside the competence of our scientific institutions—it would be tragic folly if we also were coaxed into silence about the injustices being done to our scientific colleagues and friends in that great country.

NEWS

Oil from Shale: Answer to the Energy Crisis?

by our Washington Correspondent

BENEATH a remote region of the Rocky Mountains lies a band of rock which contains enough shale oil to dwarf all the other United States domestic reserves of petroleum put together. Some 1,800 billion (US) barrels of oil are locked into the rock there, and up to a third of it is in deposits rich enough to be exploited commercially. Last week, the federal government took the first tentative step towards developing the resource, for Rogers C. B. Morton, Secretary of the Interior, announced that six tracts of federal land will be leased to oil companies next year so that they can begin producing shale oil.

Unfortunately, however, the sheer magnitude of the deposits has led to some unfounded optimism and grossly overstated predictions about the potential impact of shale oil production on fuel supplies in the United States. There are many problems ahead for those intent on developing the resource and there are factors which are likely to set physical limits on the rate at which shale oil will be produced. Thus shale oil is unlikely to provide salvation from the energy crisis, as some have predicted. But one thing is certain: the emergence of a shale oil industry will radically alter a large area of Colorado, Wyoming and Utah, and it will cause massive destruction of the environment.

The leasings announced last week will allow a prototype operation to get under way and the objective is, on the one hand, to enable the oil companies to test the technology for producing oil from shale on a moderately large scale and, on the other, to enable the Department of the Interior to take stock of the environmental damage that results. After three or four years, the companies should be able to decide whether oil shale development is commercially attractive and the federal government will be able to decide whether the environmental costs justify throwing the whole area open for development.

The six tracts to be leased next year—two each in Colorado, Utah and Wyoming—cover a combined area of some 30,000 acres; the entire oil shale

field spans some 25,000 square miles. That is an area equal in size to the state of West Virginia or three times the size of Wales. Most of the land is owned by the federal government, which is thus in a position to dictate the pace and scope of development.

It has been known for a long time that huge quantities of shale oil lie under part of the Rockies and, in fact, some oil was produced from shale deposits before natural petroleum was discovered in 1859. But the cost of extracting oil from the shale has always made it commercially unattractive—at least until the energy crisis caused the costs of other energy supplies to increase. And the Arab oil producers have now turned out to be the best friend that potential oil shale producers could possibly have, for their embargo on oil exports to the United States has turned the shale fields into a goldmine almost overnight.

Shale oil is locked into rock in the form of a solid hydrocarbon called kerogen. To get it out requires the rock to be heated to about 900° F and the gases and petroleum vapours that boil off collected. Potential oil shale producers have been experimenting for several years with two different approaches to that deceptively simple task. One involves mining the shale, crushing it and heating it in a retort. The other involves either blasting or excavating a cavern beneath the surface, burning gases in the cavern to cause oil to flow out of the surrounding rocks and pumping the products to the surface. The former approach has received the most attention and will probably be the one adopted by most of the companies that will be bidding for the leases next year.

This is how the process will work. Oil shale will be mined either by open-pit mining where it is close to the surface—only a small area of the Colorado shale fields will be surface mined—or by the simple room-and-pillar method. It will then be crushed into marble-sized pieces and fed into a retort which will initially be capable of processing up to 10,000 tons of shale a day. Several different designs of retort have been patented, and they involve heating the shale either by burning some of the oil in the rock or burning some of the gases produced from the shale. One process also involves heating ceramic balls in a separate plant and using them to retort the shale. In any case, the resulting product is a viscous, low gravity, moderate-sulphur and high-nitrogen oil.

Once the oil and gases have been extracted from the shale, the problem is then what to do with the vast quantities of rock left over. The crushing and retorting process expands the rock considerably, so it cannot be simply fed back into the mines, and the only solution will be to dump it into canyons and to build up new slopes which will then have to be revegetated. The oil shale region will thus experience something of a transformation.

The Department of the Interior reckons that the prototype operations will eventually lead to the production of some 250,000 barrels of shale oil a day and that, if full commercial development of the shale fields proves to be acceptable, 1 million barrels of oil could be produced by 1985. A simple calculation shows, however, that such a programme would be a massive undertaking, which, for a variety of reasons, may be close to the limit of production capabilities.

The sheer scale of such an operation is one stumbling block. It is reckoned that to be commercially attractive to exploit, the shale will have to contain at least 25 gallons of oil per ton of rock. Thus, for every barrel of oil produced (one barrel is 42 US gallons) two tons of rock will have to be processed and dumped. It follows that production of 1 million barrels of shale oil a day will require the mining, processing and dumping of 2 million tons of rock, and that would require a mining operation equivalent in size to the entire United States domestic coal industry. There will undoubtedly be a large increase in coal production in the next decade, so oil shale producers will be hard pressed to find the mining capacity to support a large industry.

Another, and ultimately more intractable, problem is the shortage of water in the area, for the oil shale fields lie in a semi-arid region. Water would be required in the retorting process—although one technology under study would require very little—and since an oil shale industry will lead to large urban development, there would also be increased demand for municipal water supplies. Thus, according to an environmental impact statement published in August by the Department of the Interior, "development beyond the 1-million-barrel-per-day level is possible, but at some point water availability could place a limitation on the ultimate size (of production)". A similar conclusion is reached in a study to be published in a few weeks time by the House Committee on Science and Astronautics. Thus, mining and retorting of oil shale is likely to be limited for the foreseeable future to about 1 million barrels a day which, although significant, represents only about 5% of projected demand for petroleum in 1985.

Chiefly for these reasons, a good deal of attention is now being paid to the second technology for shale oil production, the so-called *in situ* method. If it can be perfected, *in situ* production would have the advantage that little or no rock would have to be brought to the surface and eventually disposed of, so many of the environmental problems would not arise, and it would also use less water. The technology is not as well developed as surface processing technology, however, and according to the Department of the Interior, there are still some problems to be overcome. Nevertheless, the federal government is prepared to put more money into *in situ* research, for a five-year energy research and development plan being put together by the Atomic Energy Commission recommends that $126 million be spent on such research by 1980.

Occidental Petroleum claims, however, to have perfected an *in situ* process which is now capable of commercial application. According to an interview with Dr Armand Hammer, the controversial chairman of Occidental, which was published in the London *Times* on November 24, the process involves blasting a chamber into the underground shale formation, injecting natural gas into it and burning the gas. Oil runs out of the shale, into the chamber, and can be pumped to the surface. Hammer made the astonishing claim that the costs of the operation are only $1 per barrel, and he said that with massive capital investment the process could be producing large quantities of shale oil within three to five years.

Sources in the oil industry and in the Department of the Interior were sceptical of the claim last week, however, and an official of Occidental even said that he believes the claim that oil could be produced for $1 per barrel "may have been misinterpreted". The Department of the Interior also said in its environmental impact statement that "it is obvious that considerable further improvements in *in situ* recovery are still required before industrial scale *in situ* recovery could become a reality". The impact statement also suggested that a major uncertainty in the *in situ* method is what happens to subsurface movements of liquids and gases, both before and after the retorting process. There is a possibility that toxic contaminants may find their way through the groundwaters into the Colorado River, which flows through the oil shale region and provides a lifeline for several million people who live downstream.

The Occidental process has, nevertheless, caused something of a stir among shale oil developers and *in situ* production will be closely investigated in the next few years. In fact, the two prototype tracts to be leased next year in Wyoming are particularly suitable for *in situ* production.

The vast oil shale deposits in the United States are thus likely to make a significant contribution to oil supplies sometime in the future, but they are not likely either to affect the relatively short term situation or to provide final salvation.