was widely accepted and earth science was revolutionized.

Basic Energy Sciences research, focused on a seemingly unrelated endeavor, provided the crucial instrument that contributed to this advance. Moreover, technical applications of the combination of isotopic studies and geology, known as isotopic geology, are blossoming.

Today, this technology underpins studies of deep portions of the earth's crust, identification of precursors to earthquakes and volcanic eruptions, definition of geothermal reservoirs, and prediction and monitoring of toxic waste migration in aquifers and other geologic formations. Modern geology, in turn, is now returning dividends to energy technology, improving the search for oil, natural gas, uranium, and other minerals.

GAS-LUBRICATED PISTON RINGS

Because of their fuel efficiency and long life, diesel engines have long been chosen over gasoline-fueled spark-type engines for use in heavy-duty trucks. Despite their higher cost and weight, diesels have even made modest inroads into the automobile engine market. A recent invention that promises to bring about major reductions in diesel engine weight and complexity, as well as improvements in efficiency and reliability, may make the diesel an even more solid choice.

The invention involves a radically different concept for the lubrication of piston rings. Piston rings perform the critical job of sealing the hot gases within an engine's combustion chambers. The invention by a Massachusetts Institute of Technology researcher sponsored by the Basic Energy Sciences program is a piston ring that is lubricated by combustion gases blowing between an engine's rings and its cylinders rather than by an independent oil supply as in conventional internal combustion engines.

The reason the engine becomes so much simpler is that much of the cooling system water pump, water lines, thermostat, and radiator can be eliminated. Cooling requirements of internal combustion engines are set by the need to prevent the lubricating oil near the combustion zone from burning up. When oil is no longer needed there, the engine need no longer be cooled by water flowing through an elaborate system of ducts within the cylinder walls.

Because the rings ride on a cushion of gases that have much lower viscosity than lubricating oil, engine friction—a major contributor to fuel inefficiency at high speeds—is also greatly reduced. Without the lubricating oil limiting its temperature, the engine can also run hotter, thereby improving its fuel efficiency. New ceramic materials that will permit major increases in engine temperature are also being developed by the Department of Energy.

The scientific principles of thermodynamics that show that efficiency increases at higher engine temperatures apply equally to both diesel and gasoline engines, but gasoline engines have a major practical limitation. That is, gasoline would be ignited by hot engine parts before it could get to the proper place in the engine. Thus, the focus has been on engines using various types of diesel fuel, which better resist ignition by hot engine parts.

Recently, however, gas-lubricated piston rings have been considered for another reason—air pollution control. Careful studies of the combustion inside an engine show that pollutants tend to be generated most near relatively cold metal surfaces. By reducing the need to cool the cylinder walls, it appears that gas-lubricated piston rings will permit engines to run cleaner.

In the patented MIT design, the piston ring has a cross-section like a mushroom, with the stem part extending into the piston grooves. When this oddly-shaped ring twists under load, the rounded mushroom head maintains the curved, lifting surface close to the cylinder wall and allows a thin layer of combustion gases to flow between the two surfaces. The tolerance of the design is tight. The ring must ride close to the wall in order to prevent excess gas leakage, yet must not expand to seal the gap between piston and cylinder. The amount of gas required for lubrication is very small so that no more combustion gas leakage occurs than with oil-lubricated rings.

Many engineering hurdles remain before gas-lubricated piston rings are commercially feasible, but the idea of an engine lubricated by something other than oil with its relatively high friction and associated cooling systems is so attractive that the Cummins Engine Corporation has proceeded into a design and test program for heavy-duty diesel engines. NASA is also interested. The very low fric-