Coal: Energy bridge to the 21st century

The world is returning to the coal age. It's inevitable. At least that's what the authors of the World Coal Study (WOCOL), an international and ostensibly independent forecast of the mineral's prospects through the year 2000, say in a 247-page report released last week.

Coal already supplies more than a quarter of the world's energy, but the study says "coal will have to supply between one-half and two-thirds of the additional energy needed by the world during the next 20 years," even under moderate energy-growth assumptions. To achieve this, world coal production must increase 2.5 to 3 times and world trade in steam coal must grow 10 to 15 times above 1979 levels. The study's conclusion is simple: "Without such a coal expansion the [world economic] outlook is bleak."

Organized two years ago under the direction of Carroll L. Wilson, professor emeritus at the Massachusetts Institute of Technology, WOCOL came to embody 35 key industrial, governmental and academic leaders representing 16 countries. But their participation, and the participation of associates they brought in to aid them, was to be voluntary, informal and independent of their employers.

To counter declining supplies of oil — the only fuel used more than coal — and to provide a transition until alternative fuels such as solar energy gain a larger share of the energy market, coal production must climb five percent annually, WOCOL says. This goal is achievable "without unacceptable increases in cost," its authors say, but they worry that "economic, institutional, and other considerations — not technological ones — are delaying a more rapid buildup in coal use." The National Coal Association agrees. In a recent report it sent to President Jimmy Carter, it said the United States alone can mine 100 million tons more coal a year than is being used. But identifying 44 separate problems, it said coal policies and regulations now constrain the mineral's development.

Because of its abundance and versatility (it can be converted to coke, synthetic gases, liquids and chemical feedstocks), coal is one of the only alternatives to oil, natural gas and nuclear power over the near term that can rapidly increase to meet demands. And with the exception of carbon dioxide (CO_2), technologies exist to control all environmental, health and safety problems associated with a scale-up in coal use, the study claims.

In fact, CO_2 buildup and associated global climatic changes (SN: 9/8/79, p. 173) is the one unsolved problem plaguing coal's prospects. Yet conceding that burning coal liberates 25 percent more CO_2 than oil, 75 percent more than natural gas, the study still concludes that CO_2 research findings do "not justify delaying the expansion of coal use." It adds that factoring in the energy conservation anticipated over the next two decades, there might even be up to a 50 percent drop in the *growth* of energy-related CO_2 emissions. □

Chromosome changes in Love Canal victims

A pilot study looking at the blood of 36 residents in the Love Canal region of Niagara Falls, N.Y., last week identified 11 individuals exhibiting "significant" chromosome aberrations. Pending a review of the study by "recognized expert geneticists" this week, the Environmental Protection Agency will decide whether or not to recommend temporarily relocating 700 more Love Canal families or some other action.

EPA commissioned Biogenics Corp. in Houston to do the chromosome study as part of an evidence-gathering effort in connection with a lawsuit the agency is bringing against the Hooker Chemical Co. through the U.S. Justice Department. The $124 million suit charges Hooker with the chemical contamination at Love Canal.

According to Biogenics's scientific director, Dante Picciano, a nationally recognized genetic toxicologist, eight of the 36 individuals studied showed chromosome breaks and four (including one with chromosome breaks) exhibited abnormal marker chromosomes, especially ring chromosomes. Normally one would expect to find only one person in 100 or 1,000 with chromosome breaks in the blood, Picciano says.

As a result of its findings, Biogenics concludes that "chemical exposures at Love Canal may be responsible for much of the apparent increase in the observed [chromosome abnormalities] and that the residents are at an increased risk of neoplastic disease [including cancer], of having spontaneous abortions and of having children with birth defects."

Due to the small sample size and lack of comparisons against blood from a control (unexposed) group of individuals, Picciano cautions for "prudence" in interpreting the Biogenics results. Similar blood changes can result from viral infections or exposure to radiation (SN: 3/3/79, p. 133) such as diagnostic X-rays.

In a letter to EPA's Frode Ulvedal, Picciano recommends a follow-up study including a minimum of 50 unexposed individuals together with like numbers of persons who have received low-level, intermediate and high-level exposures to chemicals seeping up through the ground and into the air around Love Canal. A chromosome study of such a group should detect chemically induced chromosome changes, he said, and might even generate a dose-response relationship. □

Meeting of the moons

Although Jupiter's major moons, known for their discoverer as the Galilean satellites, were first observed centuries ago, it was not until last year that earthlings first got a good look at them, and the results were amazing. The exotic features and diversity of Io, Europa, Ganymede and Callisto abruptly placed them high on the list of the list of Most Intriguing Objects in the Solar System, and last week nearly 200 researchers met in Hawaii in an international colloquium called expressly to discuss and exchange information on the quixotic quartet.

Clearly monopolizing the gathering's attention was Io, which accounted for nearly half of the 133 formal presentations and probably a similar proportion of the conversations in hallways, restaurants and even on the lava-strewn beaches. Io's active vulcanism, sulfur-rich surface, ionized outpourings, brilliant coloration, strange electrical properties and other phenomena make it perhaps the most bizarre planetary body yet studied, and last week's meeting served to add yet another twist:

"Even when it's trying to look ordinary," said one participant, "Io just gets stranger." The latest analysis of the satellite's shape indicates that it may be, of all things, *too round* — with baffling consequences. Io, less than 30 percent of the diameter of the earth, is far more internally active (SN: 4/19/80, p. 251), sending some of its volcanic plumes hundreds of kilometers into space and (as three separate meeting reports seemed to agree) giving off about 30 times as much heat per unit area as the earth does. The favored explanation for Io's raging innards is that it is pulled out of shape by Jupiter's gravity, which creates a bulge that is cyclically wrenched in and out and back and forth as Io follows its elliptical orbit (a path kept out-of-round by the perturbing influence of Europa, the next satellite out from the planet). According to the theory's proponents, the tidal distortion causing the bulge should make Io's radius about 12 kilometers greater in the Jupiter-pointing direction than in the north-south direction. But according to Merton E. Davies of the Rand Corp., who has been calculating the satellite's shape using measurements from photos taken by the Voyager 1 and 2 spacecraft (which also revealed the vulcanism), the difference appears to be less than 4 km.

The seemingly small discrepancy threw the Io researchers into a tizzy. Either the bulge is unexpectedly small or the satellite is too fat in the polar direction. If the difference is the bulge's fault, scientists must consider the possibility that Io's outer layers are more rigid than the calculated amount of tidal heating ought to allow. If the polar radius is too great, it could mean

that the poles are piled high with low-density material tossed out by the vulcanism, except that the poles happen to be just the parts of Io in which currently active vulcanism has not been found. Faced with Davies's numbers at the meeting for the first time, scientists posed various possible solutions, but all so far have their problems — such as the one that requires Io to be "rolling" along its orbit so that its poles change position by 90° in as little as 10,000 years. The missing eight kilometers have now upset, at least for the moment, much of what little understanding of Io's interior was thought to exist, and the result, says Torrence V. Johnson of Jet Propulsion Laboratory, is "an extreme quandary."

Another question has been whether Io has an atmosphere, given that gas seems to be a major component of its volcanic eruptions. Voyager infrared data indicated 0.2 centimeter-atmospheres (about one ten-millionth of earth's total surface pressure) of sulfur dioxide gas in a measurement made near an erupting plume, but the implications for the whole of Io are not so clear. According to Fraser Fanale of JPL, the localized 0.2 cm-atm. measurement was taken near Io's subsolar point, where the sun's heat is greatest (thus releasing a maximum of the frozen SO_2 that has been identified in spectra of the surface), and thus ought to imply an average pressure for the whole of Io of about one-fifth that amount. Yet measurements made by the earth-orbiting International Ultraviolet Explorer satellite indicated a global pressure that was five times smaller still, a mere 0.008 cm-atm. The answer, Fanale suggests, may be that Io's SO_2 atmosphere is confined to a near-equatorial band, where most of the eruptions were seen, since the SO_2 molecules migrating from there toward the poles could be picked off during the trip by charged particles in Jupiter's Io-enveloping magnetic field. He says that this could also explain why Io's poles appear darker than the rest of the surface.

The rest of the Galilean satellites, different as they are from one another, share one quality that sets them apart from sulfur-clad, eruptive Io: All are wrapped in thick blankets of ice, cracked and deformed by a variety of barely understood processes. Ganymede, the largest of the group, is crisscrossed by strange patterns of parallel grooves (SN: 5/17/80, p. 315), which Eugene Shoemaker of the U.S. Geological Survey told the meeting look as if they formed when the satellite's whole crust was in tension. Such stress could have been caused by the expansion of underlying strata of dense ice, Shoemaker believes, although, he says, any actual increase in Ganymede's radius would probably have been less than one percent. Fissuring on such a scale might also be expected to cause significant secondary effects, as suggested by Stephen W. Squyres of Cornell, who proposed water rising through the cracks as the origin for a 260-kilometer-wide dome that he said looms some 2.5 km above Ganymede's surface.

The opposite, in a sense, of Ganymede, which has cracks, craters, domes, smooth spots, rough spots and more, is Europa, on which the Voyager photos revealed almost nothing but tangled patterns of streaks — wide, narrow, light, dark, straight, curved and often interwoven (SN: 5/3/80, p. 283). The streaks, like Ganymede's grooves, are believed to be fissures and ridges due to stress on the ice, but they apparently vary by no more than a few hundred meters at most from the surrounding terrain. Trying to unravel the gnarled web, Lawrence Soderblom of the USGS reported that they seem to have formed in three separate episodes — two "one-shot" batches and one grouping that resulted from some longer-term process. Some expansion of Europa would probably have been needed to do the trick, he told the meeting, such as might have occurred when rock settled to the center of the satellite's original mixture of materials to leave the ice on top. But there is a moonful of cracks to be explained, and although Europa shows traces of only eight craters that Soderblom and a colleague could even agree were craters, it is possible, he said, that their formation also had something to do with creating the stripy surface. Even tidal stresses could play a role, as E.M. Parmentier and colleagues from Brown University have suggested, although Europa is farther than Io from Jupiter and may be subjected to only a tenth as much Jovian tidal stress as causes Io's vulcanism. David Pieri of JPL identified further signs of such a process, citing the pattern of polygons created by the intersecting streaks as evidence for stresses on Europa aligned around its Jupiter-facing side.

The odd moon out is Callisto, at least compared with the exotica of the other Galilean satellites. Callisto shows no volcanoes, no cracks, no mountains — virtually nothing but craters, packed side by side over the entire surface. As the outermost of the four major moons, it is not subjected to significant tidal stresses, nor does it show the grooves that on Ganymede (the next satellite in) are tentatively being attributed to tensional stresses from expansion or other factors. As with Ganymede and Europa, however, Callisto's craters do show up as bright spots or rings against a darker surface — a darkness that raises questions about what are essentially ice-jacketed worlds. Micrometeoroid dust could presumably account for some of the dark material (the satellites' own rocky stuff supposedly would have sunk to the center), and William K. Hartmann of the Planetary Science Institute in Arizona said that different heating histories for the moons could make major differences in whether such dark layers would stay on the top or form strata at varying depths.

More mysteries remain. □

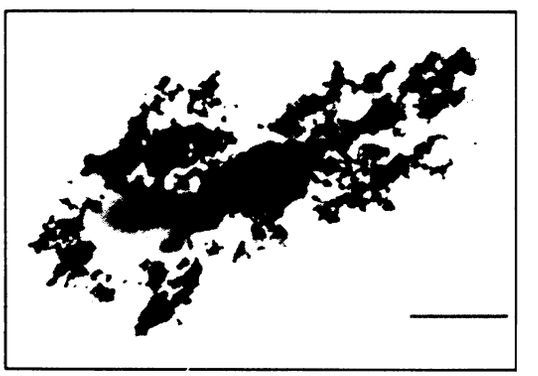
Homing pigeons: A magnet in the neck

There is some bewitching magnetism about the mission San Juan Capistrano that brings the famous swallows back every year. It's a bit harder to believe that there is any magnetism about a guano-covered coop on a roof in downtown Pasadena that brings pigeons back again and again. Unless it really is magnetism. A number of researchers investigating the homing and migrating behavior of various birds, bees and other species are beginning to believe it is magnetism, geomagnetism. A method by which birds may use geomagnetism to such a purpose is proposed by David Presti and John D. Pettigrew of California Institute of Technology in the May 8 NATURE.

Evidence cited in support of the view that magnetism is somehow involved include behavioral experiments that show that changes in the ambient magnetic field affect animals' ability to orient themselves and dissections that have found magnetic material in the bodies of birds, bees and others, including the finding of magnetic chains in some bacteria and the observation that those bacteria seem to use the internal magnets for direction finding (SN: 4/26/80, p. 267).

Presti and Pettigrew propose that the birds get information about the geomagnetic field through a sensory apparatus that resides in a muscle. It is a combination of a small permanent magnet that responds to the geomagnetic field and a sensitive part of the muscle, a spindle fiber that is influenced by the magnet. As a basis for this suggestion they cite anatomical evidence gathered from dissections they did of two species of migrating and homing birds.

The specimens included pigeons *(Columba livia)*, both tame and feral, and migratory white crowned sparrows *(Zonotrichia leucophrys)*. A high degree of inducible magnetic remanence was found in the heads and necks of the birds. Such a finding indicates the presence of magnetic material. The birds were prepared with a buffered fixative for fear that the acidity of



Nature

Magnetic particles found between complexus muscle and fascia of a pigeon.