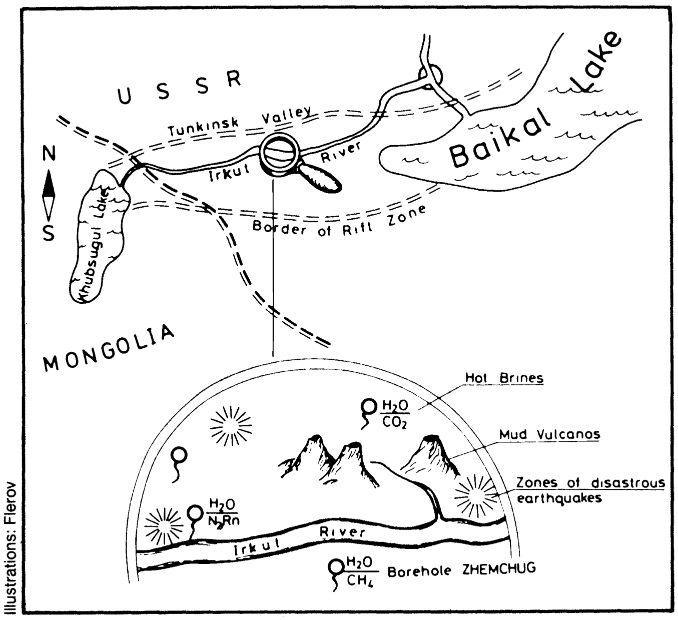
Discovering Transuranic Elements at Dubna



Illustrations: Flerov

Near Lake Baikal Soviet scientists are digging wells for hot brines in which to look for transuranic elements.

By DIETRICK E. THOMSEN

The search for transuranic elements, chemical species heavier than uranium, is an attempt to extend the frontiers of both chemistry and nuclear physics. An extremely difficult endeavor for the experimenters involved, it is nevertheless fairly easy for outside observers to follow. Each achievement in turn can be marked on a scorecard — the periodic table of the elements. One by one the blanks are being filled in on the way to the so-called "island of stability," whose existence theorists predicted 20 years ago. This is a range of relatively stable nuclei with atomic numbers just above 110. Possibly they might be stable enough to be of some use for something.

The transuranics are all inherently unstable, subject to spontaneous fission or radioactive decay — as is uranium, atomic number 92, the heaviest element known to exist in detectable amounts on earth. In the search for transuranics, experimenters take two general approaches. Either they try to manufacture them by setting up fusion reactions involving lighter nuclei, or they look for traces of them in somewhat exotic minerals, such as meteoric debris or certain hot brines.

Up to now all the successes — all the detections of new elements that have gained the acceptance of the scientific community — have come from induced fusion reactions or bombardment of nuclei with energetic neutrons. The other approach has not been as fruitful. According to one of the leaders in the field, Georgy N. Flerov of the Joint Institute for Nuclear Research at Dubna in the Soviet Union, searches of minerals have shown evidence for fission events that cannot be assigned to known species, but no kind of identification has been possible.

So far the heaviest element claimed by any researchers in the field is element 110, which has been the object of experiments by a Dubna group led by Yuri Oganessian. Flerov recently sent Science News two papers — one on Dubna's latest work on this element, authored by Oganessian and 15 other scientists from the Soviet Union, Romania, France and the German Democratic Republic, the other a review of the program in general, in which Flerov expresses his belief in the feasibility of going for atomic numbers higher than 110.

A number of laboratories in several countries have participated in the general search for elements heavier than uranium, but up to now the main laboratories involved in claims of discovery have been Dubna, where Flerov has guided the world for decades; the Lawrence Berkeley (Calif.) Laboratory, where Glenn T. Seaborg has been the overall leader; and the Gesellschaft für Schwerionenforschung (GSI) at Darmstadt, West Germany. GSI, which has an unconfirmed claim to element 109, is now trying to confirm the apparent discovery of element 110.

The earliest discoveries of transuranic elements came out of weapons research during World War II. Later, scientists using the technique of bombarding selected targets with accelerated ions in the hope of making two nuclei fuse into a bigger one experienced several successes, including the generally accepted discoveries of elements 104 and 105 as well as claims to the discovery of some of the higher numbers. Then followed a long period of difficulty to which Flerov refers in one of the papers he recently sent to Science News. The difficult period led many experts to conclude that the island of stability would never be reached, but Flerov remains optimistic. In his review paper he writes, "In our view, however, attempts to produce new elements with [atomic numbers equal to or higher than 110] can and must be pursued." Dubna's first evidence for element 110 was reported a little less than two years ago (SN: 5/17/86, p.319).

The experiments are usually done by selecting a fusion reaction calculated to yield a particular transuranic element. Experimenters determine the appropriate reaction by adding up neutrons and protons in the reacting elements, making allowance, where nuclear dynamics demands it, for the release of one or more free neutrons in the reaction. Then they bombard targets made of one element with accelerated ions of the other.

The key to finding a new transuranic element is the observation of a source of nuclear fission or of alpha-particle decay that does not correspond to any nuclear species already known. Such activity can be attributed to the particular transuranic element being sought, and on this basis several claims have been made, including Dubna's claim to element 110, as related in the previously mentioned paper by Oganessian et al.

For certainty, however, the scientific community at large requires specific kinds of confirmation, particularly the identification of the products of the fission or the alpha decay to see that they are the nuclei that nuclear dynamics would expect to come from the transuranic element in question. The identification is extremely difficult, as the quantities involved are minute — often no more than a few atoms. Discoveries of elements 104 and 105 are generally accepted on this basis. Claims to higher atomic numbers, particulrly 110, still await that kind of confirmation.

The names of elements 104 and 105 remain in dispute, as Berkeley and Dubna both claim to have been the first to have solid evidence for their existence, and each has proposed different names. Anticipating more such disputes, the International Union of Pure and Applied Physics has devised a neutral temporary naming system that simply translates the numbers into syllables: "un" for 1, "nil" for 0, "quad" for 4, "pent" for 5 and so on. In this scheme, element 104 is unnilquadium and element 105 is unnilpentium. Element 110 would be something like "ununnilium."

As Oganessian and his colleagues describe them, the most recent experiments on element 110 involved bombarding uranium-236 with ions of argon-40. The ions were accelerated in Dubna's U-400 cyclotron to an energy of 265 million electron-volts (265 MeV). One of the great difficulties in this work is to separate the formation of compound nuclei from all the other reactions that may take place in such collisions. The Dubna group did a number of control experiments with various substances to estimate the rates of such other reactions and to determine how to recognize them and separate them from the wanted one. In the end they discovered instances of spontaneous fission that did not correspond to anything they could identify. They concluded that these fissions are due to the activity of element 110. Unfortunately, as Flerov points out, the GSI experiments so far have not been able to confirm 110.

Experimenters need to identify the products of such unusual fission or other radioactivity to determine precisely what is going on. Toward this end, the Dubna group is preparing a detector called Vassilissa, which will be similar to one already in place at GSI. Vassilissa will capture the nuclei that recoil off the targets after bombardment. It will put them through electric and magnetic fields to control their motion and then introduce them into a detection chamber, where they may be identified by how they drift in an electric field, how they exchange electric charge with other species and even how they interact with a gas introduced into the chamber for the purpose.

In addition to the induced fusion experiments, the Soviet scientists have undertaken searches of natural mineral samples for evidence of transuranic elements that may exist in nature. Flerov mentions that for several years the Dubna group looked for heavy nuclei in the cosmic rays. In crystals of olivine taken from some iron-stony meteorites, they actually found some tracks that might have been caused by such heavy nuclei being stopped in the olivine. However, Flerov says, "the assumption that the anomalous tracks detected belong to the cosmic-ray nuclei of superheavy elements remains unproved . . . ."

Another possibility is to look for evidence of spontaneous fission activity in meteoric material and also in hot brines taken from abyssal fractures of the earth's crust. Flerov says that Soviet researchers are now drilling holes in the Central Asia and Baikal rift zones to obtain such hot brines.

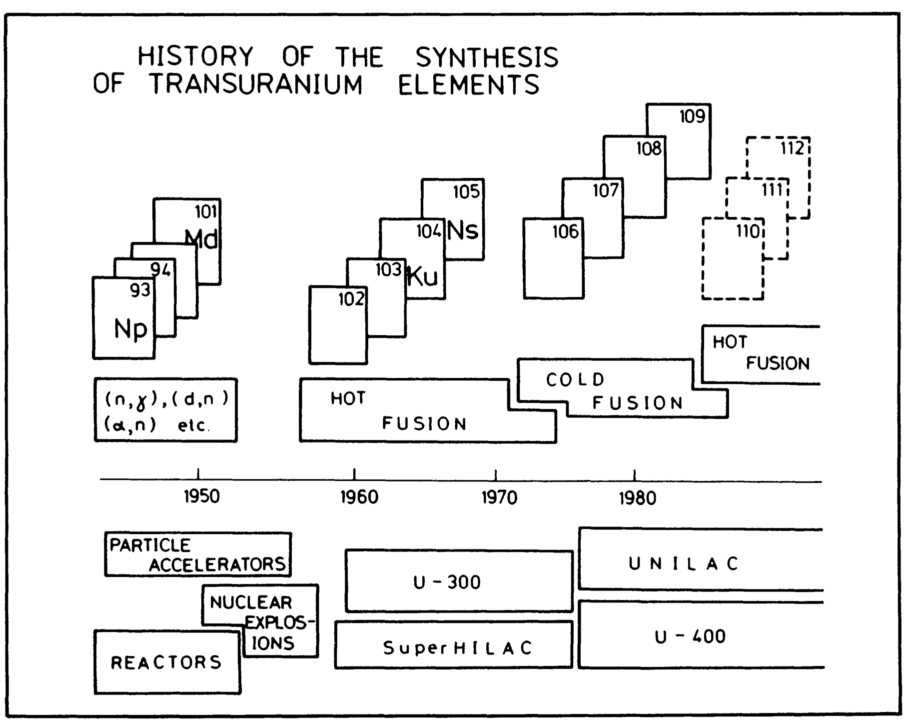


Chart of the transuranic elements shows the kind of reaction in which they were made (just above the date line) and the kind of experiment or specific piece of equipment that made them (below the date line).

Meanwhile, meteorite samples and hot brines have yielded some tantalizing evidence of spontaneous fission. "There is a great temptation to admit that the observation of these events is indicative of the existence of a spontaneously fissioning superheavy element in nature," Flerov writes. "However, the average number of spontaneous fission neutrons turned out rather small, close to the value observed in the fission of actinide nuclei. Therefore, it cannot be excluded that the spontaneously fissioning nuclide observed is an isotope of a radioactive element heavier than bismuth, but which has been produced in an unusual state in the process of natural nucleosynthesis."

Flerov says he wants to investigate these indications seriously. However, the low rate of activity and small amount of meteoritic material available hinder the work. He cites a piece of the famous Allende meteorite, "kindly provided to us by Dr. R. Clarke of the Smithsonian Institution [in Washington, D.C.]," in which the count rate was as low as 1 event per 50 days per 1 kilogram of meteorite.

This means that researchers will need to assemble several tons of meteoritic material, and the world's museum and laboratory collections do not contain that much. However, Flerov points out, there is plenty of meteoritic material around if one knows where to look. One place is the bottom of the ocean. "Meteorites that have fallen during the last 10 million years are accessible for transportation to the surface in the regions of deep-sea hollows where the rate of sediment accumulation does not exceed 1 millimeter per million years," he writes.

Another possible source is certain sedimentary rocks formed during a particular 1,000-year period about 65 million years ago. "Geochemists have concluded," writes Flerov, "that these rocks contain a considerable amount of meteoritic dust produced as a result of sputtering of a hypothetical cosmic body that had undergone a collision with the earth."

If elements heavier than uranium exist naturally somewhere in the universe, scientists may find them by this kind of sifting of minerals that come from beyond the earth. However, they have been at it for 40 years without any real success, in spite of some tantalizing findings. Meanwhile, sifting through the results of laboratory experiments atom by atom, scientists have proved that they can manufacture several of the transuranics. The predicted "island of stability" now lies just beyond the edge of current experiments. By one means or the other, Flerov and Oganessian believe, this group of scientifically interesting and possibly useful elements will someday be reached. □