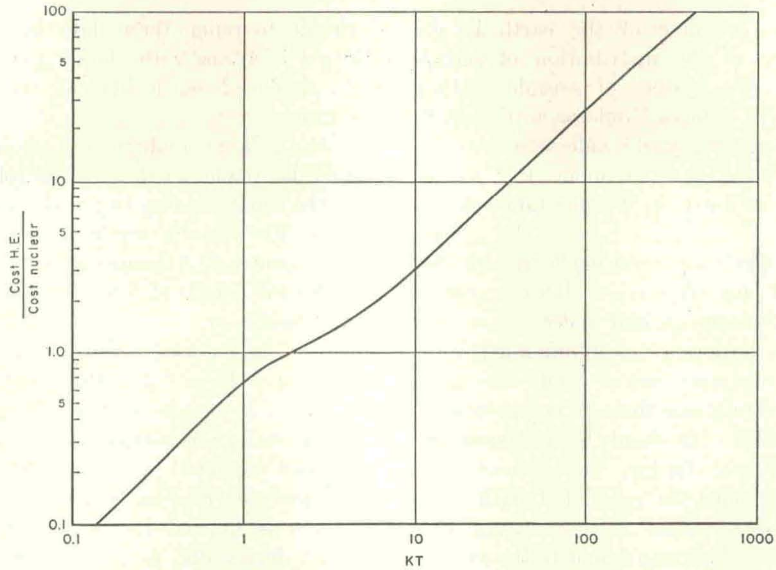


Fig. 2. Relative cost of high explosive and nuclear devices versus yield.

The most effective way to use large chemical explosions on land for seismic purposes is to detonate them in deep lakes. A kiloton of chemical explosive fired at a depth of 100 meters in a lake 200 meters deep should give a stronger seismic signal than the 20-kt Blanca shot, which was detected by standard seismic stations in Europe.

So far, we have talked entirely about the sources, but the greatest rewards will come only from much greater emphasis on instrumentation, and on the theory of seismic sources and propagation. Then, once precise seismic data are in hand, we will need advances in solid-state theory and experiment to derive from these seismic data the maximum information as to the constitution and temperature of the interior of the earth.

## Proposed International Program of Explosions for Seismological Research

The program we propose is based on the assumption that funds will be available for seismology commensurate with its importance to the science of geophysics. Although nuclear explosions form an essential part of this program, the scientific potential of such explosions cannot be realized without great augmentation and improvement of seismic instrumentation. Each nuclear explosion should also be preceded by a series of chemical explosions to set the stage for reaping the full rewards from these unique sources of seismic energy.

### *Goals of the proposed program*

We shall first list the scientific objectives of the proposed program and then outline a way in which these objectives might be achieved. The goals are as follows:

*Rounding out the seismic coverage of the earth.* The aseismic regions of the earth are little known seismically. For example, since Antarctica has very few earthquakes, little is known about its structure. Only meager information [e.g., *Press and Dewart*, 1959] is available as to whether it possesses typical continental structure, whether it has a predominantly oceanic crust, or whether it is intermediate in character. Surface waves excited by a large nuclear explosion in Antarctica or in the deep ocean near Antarctica, if recorded by appropriately located stations in Antarctica, could be used to determine the thickness and extent of the continental crust. Higher-mode surface waves from a buried nuclear explosion within Antarctica may yield the over-all average ice thickness, data much sought after by geophysicists.[3]

[3] Since this was written an Antarctic Treaty has been presented which precludes nuclear explosions in Antarctica.

The seismic coverage of the earth is also spotty because of the distribution of seismic observatories. The system of seismic stations proposed by the Geneva Conference of Experts would vastly improve world-wide seismic coverage and could greatly augment the seismic results to be obtained by the program outlined below.

*Refinement of velocity versus depth relations and delineation of the differences between mantle velocities under continents and under oceans.* To this end, it is necessary to obtain much more accurate travel-time curves and amplitude versus distance relations through comprehensive refraction profiles with closely spaced seismometers and accurate timing. Surface-wave dispersion studies must be correlated with these refraction profiles, since surface waves give valuable additional information as to the average elastic properties of the layers in which they are propagated. Reflection studies should be made in the degree to which they are possible.

These efforts must be planned so as to reveal the details of the low-velocity layer (or decreased-velocity gradient) in the outer few hundred kilometers of the mantle. Of special interest are regional differences in the behavior of this layer, e.g., under continents and oceans. Oddly enough, there is more argument among seismologists about the seismic character of this outer shell of the earth than about any of the deeper parts of the earth. This is precisely the region which it is essential to know well in order to arrive at valid theories of the origin of continents and oceans, the genesis of mountains, and the source of volcanic lavas, ore bodies, diamond pipes, and all other geologic features which have their origin below the continent crust.

*Increased knowledge of the earth's core.* The presumption that the earth's core is composed of an outer shell of molten iron and an inner core of solid iron rests on shaky evidence—the fact that shear waves are not propagated through the outer core, for example, and the analogy between the mantle and the core on the one hand and the stony and iron meteorites on the other. It is possible to learn very much more about the core with nuclear explosions and improved instrumentation.

The outer boundary of the core has been shown by earthquake seismology to be a transitional region some 200 km thick. It is highly desirable to refine these data by explosions in selected locations with closely spaced seismometers deployed on a line at the appropriate distance.

With a large underwater explosion, efforts should be made to detect multiple reflections from the core boundary to get additional information on the velocity gradient and possibly the density contrast. Attempts should also be made to learn the details of $S$-wave attenuation in the transitional zone.

If the inner core is solid, it should transmit shear waves formed by $P$-$S$ conversion at its boundary. A search should be made for the $PKJKP$ wave whose travel time and amplitude have been predicted by *Bullen* [1951].

The accuracy of velocity determinations within the core is limited by inadequate knowledge of time delays due to crustal structure in the neighborhood of seismic stations. Two remedies are suggested: (1) Determine the local seismic velocities on the appropriate arrival paths by a series of refraction and reflection profiles (2) Deploy seismometers on the deep ocean floor where the crust is known to be thin and uniform. Either of these is relatively expensive, but both would be very rewarding in providing all kinds of by-product information.

*Resolution of other outstanding problems of seismology (typical examples).* (*a*) Long-period $G$ waves ($T \sim$ 100–200 sec) from large earthquakes are received at Pasadena from both directions around the earth, and hence the distance to the epicenter can be determined. Epicenters determined in this manner occasionally differ by as much as 200 km from the epicenters determined for the same earthquake by the short-period $P$ waves. Also amplitudes show a corresponding sensitivity to the direction in which the waves left the source. Large underwater nuclear explosions might generate long-period surface waves, allowing a similar comparison. If such a difference in apparent epicentral position is found for explosion sources, the effect is one of propagation. If these differences are not found in waves from explosions, the effect is one of earthquake mechanism and may be used to learn more about the nature of earthquakes, especially the extent of faulting.

(*b*) *Ewing and Press* [1956] suggested that the long-period nature of $S$ waves is due to preferential attenuation in the outer mantle.