

# U.S. COAST AND GEODETIC SURVEY GEOLOGICAL ECHO PROFILING PROGRAM

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During August and September of 1962, the United States Coast and Geodetic Survey Ship *Explorer* completed a 2 200 square nautical mile Geological Echo-Profiling (GEP) survey in the Gulf of Maine. Primarily a hydrographic survey with a trackline net-work totalling over 3 000 nautical miles, it was also one of the largest unclassified sub-bottom echo-profiling surveys ever completed. It was significant in being the first of what is planned to be a continuing series of sub-bottom studies by the Coast Survey and is part of "a general reorganization to extend and exploit the scientific and technological potential of the Survey" (KARO, 1961).

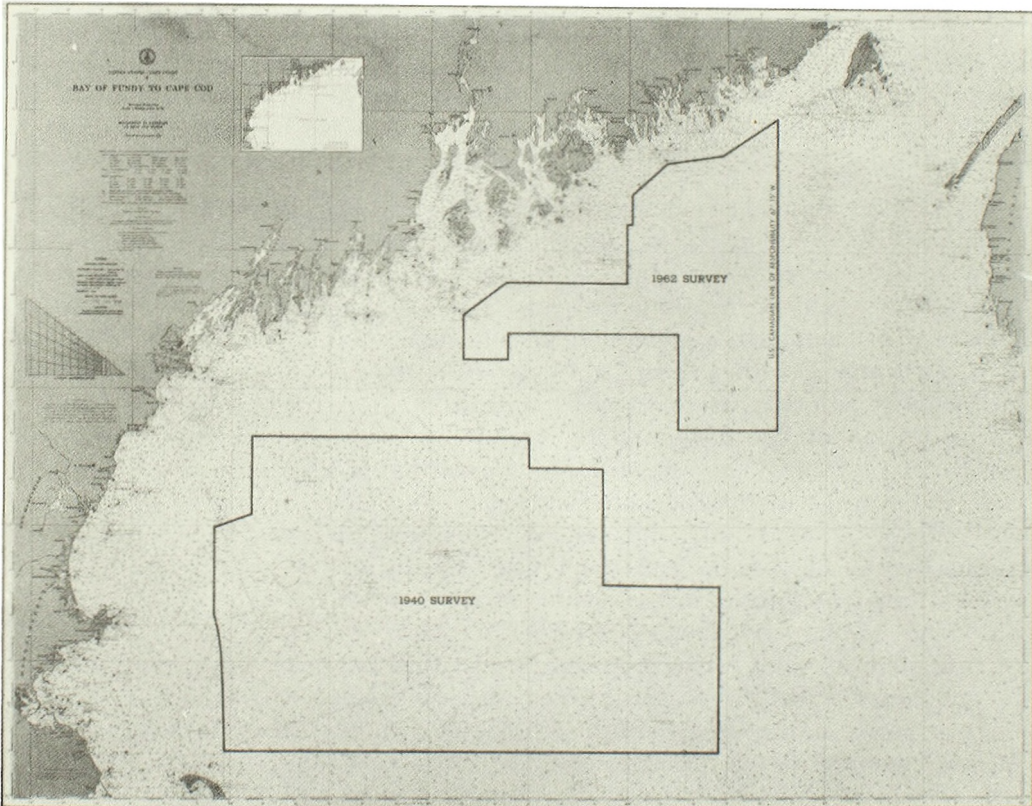


FIGURE 1

The first publication on sub-bottom echo-profiling was prepared by the Coast and Geodetic Survey from data obtained aboard the USC & GSS *Oceanographer* in the Gulf of Maine in 1940 (MURRAY, 1947). See Index Map, (Figure 1). MURRAY published 231 cross sections obtained from the Hughes-Veslekari Graphic Recorder through the easily penetrated sediments in the Gulf of Maine. The USC & GS is adopting the present profiling program to supplement its sea-floor topographic surveys. Using the high power, low frequency "sparker" sound source to accompany the depth recorders, data of the sub-bottom as well as the sea-floor will be gathered. The new program is particularly attractive because it produces valuable information of the sub-floor, is compatible with the towed proton free-precession magnetometer, and is relatively inexpensive both initially and as a continuing program. GEP operations are compatible with routine hydrography to 12 knots in water depths greater than 25-30 fathoms. In shoal waters, ship's noise reflected and refracted from the sea-floor necessitates surveying at slower speeds depending on noise characteristics of the ship employed.

With few exceptions, sub-bottom profiling in the United States has been done by consultants to exploration and engineering firms for oil and mineral exploration and for foundation and dredging studies and other engineering projects. These data, for the most part, are confidential, as are many studies undertaken or sponsored by the military. Those agencies and institutions involved in sea-floor studies, which do make their findings available to the scientific community, have not the ships nor the funds needed to do detailed hydrographic surveys of large areas. Because of the nation's increasing interest in oceanography, the C & GS plans to conduct and make available the results of extensive sub-bottom studies, while carrying out their statutory obligation to chart the nation's waterways.

Coast Survey ships run dense patterns of tracklines over selected and usually contiguous areas of the sea-floor. These surveys are controlled by accurate electronic positioning techniques such as the Raydist which was used in the Gulf of Maine project. Ships so engaged present opportunities for the compatible collection of additional data. The use of "ships of opportunity", while having obvious economic advantages, often creates problems in reducing the scattered data into meaningful terms. In contrast, the collection of sub-bottom data during hydrographic surveys combines the thrift of "ships of opportunity" operations with the well controlled, orderly coverage of hydrographic surveys. This does not mean that areas will not be studied independently of hydrographic surveys. Areas such as the Straits of Florida and the lower Chesapeake Bay have had special sub-bottom profiling studies made over them. The experimental GEP prototype, being portable, is useful in these special studies and will be retained as such. Oceanographic institutions have been encouraged to cooperate with the Coast Survey in joint sub-bottom investigations. Such a study has been recently completed with the Virginia Institute of Marine Sciences in the Chesapeake Bay. The Coast Survey independently has scheduled short-term sub-bottom studies, such as the one undertaken in June 1962 aboard the USC & GSS *Hydrographer* in the Florida Straits. Two additional special GEP surveys have been scheduled: one in March

1963 near the Alabama-Florida coast and the other in June 1963 off San Francisco, California. This latter area is the Coast Survey's Oceanographic Experimental Equipment Range and the profiler will be used to add another dimension of the sub-bottom to those being studied by other geophysical tools, such as the ship-borne gravimeter and the towed magnetometer.

In addition to the portable GEP equipment, two more units are to be permanently installed on the Coast Survey's new ships, *Whiting* and *Peirce*.

The instrumentation and techniques employed in sub-bottom echo profiling are similar to those used in routine echo-sounding. The main difference is the more intense and lower frequency energy used. This energy is generated by discharging an electric spark in the sea which ensonifies the water with a high level, short duration, low frequency, omnidirectional pulse, with maximum energy concentrated between 200 and 900 cycles per second. Repeated spark discharge explosions are synchronized with vertical scans of the recorder. Echoes returning from the ocean bottom and from the sub-bottom acoustic interfaces are detected and recorded, forming a vertical cross-section of the geologic structure beneath the track of the ship. (Figures 2 and 3).

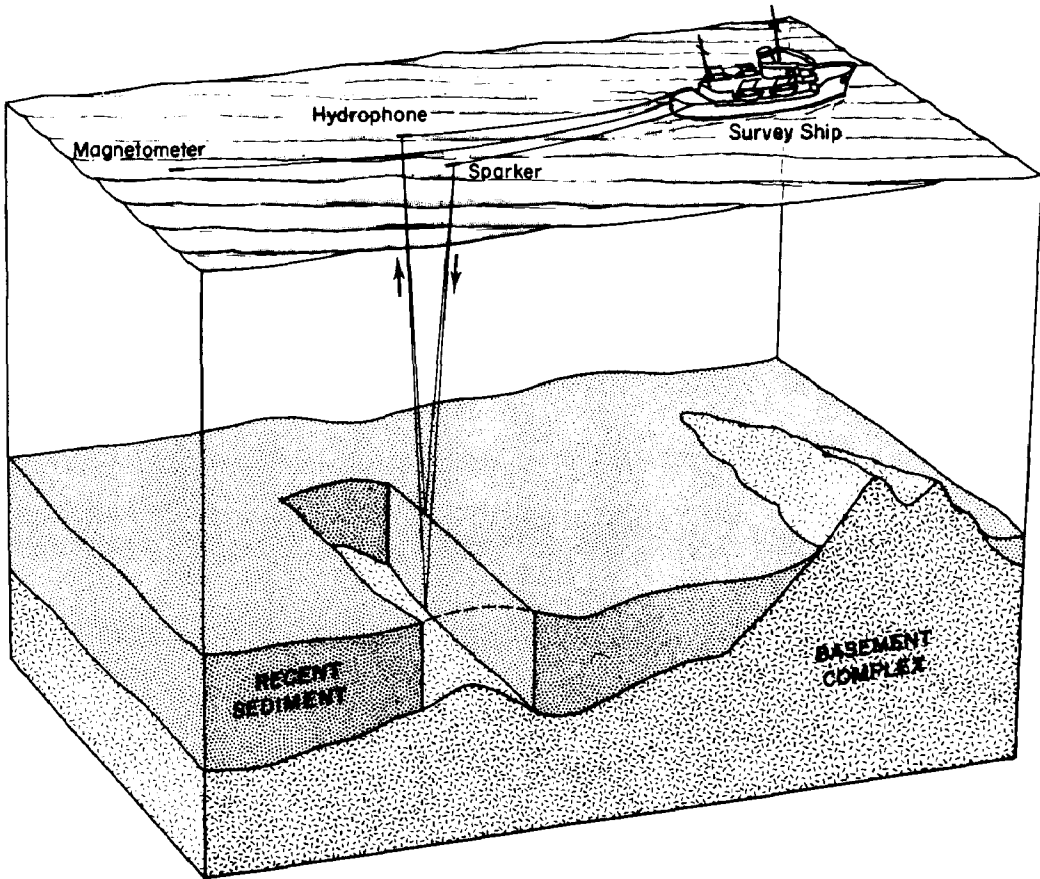


FIGURE 2

The "sparker" was originally developed by the Woods Hole Oceanographic Institution (KNOTT and HERSEY, 1956). Further development by Alpine Geophysical Co led to the present model (BECKMAN and ROBERTS, 1959).

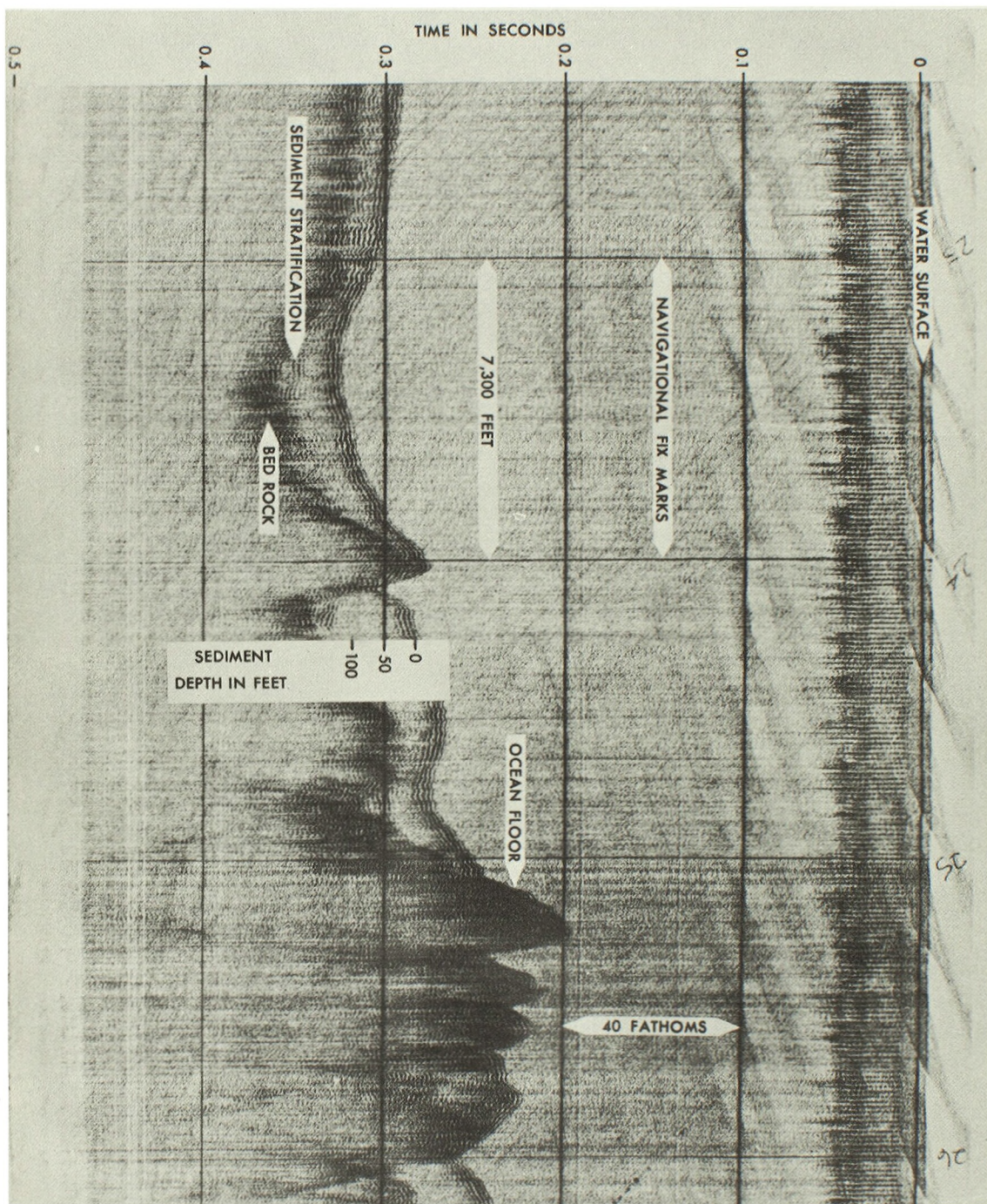


FIGURE 3

Depth of penetration of the sub-floor is directly proportional to the pulse length and the wave length of the sound used. The GEP has two power supplies available for the operator's option, affording a degree of versatility. Still, it represents a compromise between short duration, high frequency profilers such as the 3.8 KC Sonoprobe (McCLURE and HUCKABAY, 1957), at one end of the spectrum, and the electrical profilers being manufactured now which rival high explosive seismology in penetration obtained. Several other methods have been devised to transduce repeatable explosive energy into the sea for profiling, but the Coast Survey chose the "sparker" transducer for ease of towing, simplicity, safety to shipboard personnel, and its minimal maintenance requirements. The present GEP equipment is portable and consists of two 3 KW diesel generators, a 7 ft  $\times$  7 ft  $\times$  7 ft aluminum instrument shelter housing the recorder and two power supplies, an electric arc sound source transducer with 350 feet of tow cable, and a hydrophone array with 350 feet of tow cable. It is designed to be operational with one man per watch and to be completely independent of the ship's electrical power.

The 3 KW diesel generators are used for electrical power. One generator supplies current to a 200-Watt amplifier to provide precision 60-cycle power to the recorder. The second generator supplies current to either of the two power supplies. See block diagram of circuitry, Figure 4. Power supply A was manufactured by Edgerton, Germeshausen and Grier Co., to power their "Boomer" transducer. Power supply B was manufactured by Alpine Geophysical Co. Inc., to power their "sparker" transducer. The gross circuitry description is applicable to either unit. The Alpine power supply was used exclusively in the Gulf of Maine project. The electrical energy is released from the capacitors to the transducer by way of an air switch. This switch consists of a small gap between two tungsten electrodes. The switch is "closed" by a small current triggered by the recorder at the desired firing intervals ranging from once every 12 seconds to as often as 8 times a second. The triggering current sparks from a small electrode positioned between the large electrodes to the nearer electrode. This ionizes the air gap sufficiently to allow arcing of the main current to the sound transducer where another arc takes place in the water. The resulting explosion is comparable to the power generated by an engineer's blasting cap when using the larger power supply, and is proportionately less using the smaller power supply.

The same transducer is used with either power supply. It consists simply of the terminals of two insulated and shielded cables towed 350 feet behind the ship beside the hydrophone array. High voltage is pulsed through one cable which terminates in a replaceable tungsten electrode, and arcs to the grounded return cable to complete the circuit.

The hydrophone array was manufactured by Alpine Geophysical Co. Inc., and consists of 10 hydrophones (two sets of five in series) sealed into a streamlined, water-filled plastic tube, 12 feet long. A tail of flexible air-filled thermoplastic tubing trails the array for towing stability and to provide buoyancy in case of separation of the hydrophone cable. The array is towed 350 feet behind the ship to avoid picking up excessive ship's noise. With the array towed so far aft, the ship acts as a point-source of sound

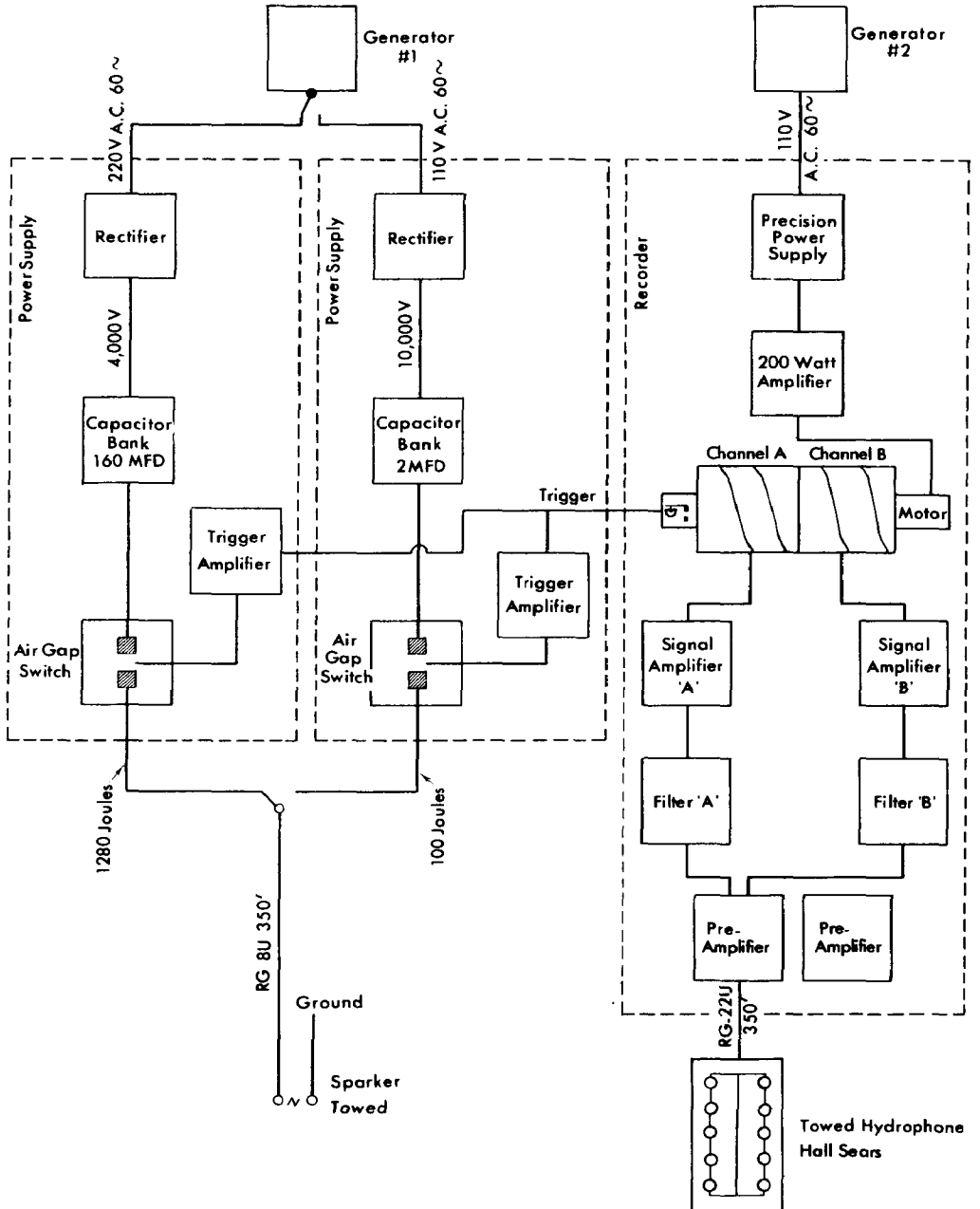


FIGURE 4

or noise. These sound waves pass the array at right angles so that wave lengths over 12' long (400 cps) are nulled by half wave length cancellation. When echoes from the sea-floor and from within the sub-bottom strike the flexible array, the enclosed pressure-sensitive hydrophones, acting as one, transduce the pressure pulses into electrical pulses.

Electrical currents generated by the hydrophones are conducted along

an insulated shielded cable to the ship where they are pre-amplified, divided into two channels, separately bandpass filtered, amplified again and finally printed on 19" electro-sensitive paper by an Alden Electronic & Impulse Recording Co. Inc., dual channel, facsimile recorder. Two records, each 8½" wide, are produced, similar to fathograms, but with the addition of sub-bottom data, (Figure 3). To one channel of the dual recorder are usually filter-passed the lower frequency (under 600 cps) signals which have returned from the depths of maximum penetration. To the second channel are customarily filter-passed the higher frequencies (over 600 cps) for finer resolution of the events in the upper reaches of the penetrated section.

Echo events from the hydrophones reach the helical contacts of a rotating drum as electrical pulses. As the rotating helices impinge on a blade parallel to the drum, a "flying spot" type of "stylus" sweeps the record vertically depositing permanent smudge-proof ferrous ions on the record. Speed of rotation of the helix drum determines the scanning time. Rotation rates of 1, 2, 4, and 8 times per second result in depth intervals of 2 400, 1 200, 600, and 300 feet (assuming a velocity of 4 800' per second). By manual depth phasing, discrete depth intervals can be displayed on any one of the four scales. A programming switch setting determines on which of the sweeps the returns are recorded after the sparker fires. Usually the first sweep is recorded. If depths are excessive, or if a shorter time interval is to be expanded on the profile, any sweep up to the twelfth after the sparker is fired may be recorded.

The distribution and thickness of unconsolidated sediments on the Continental Margins are the most immediate and useful data retrieved with such equipment. This kind of information has many applications in hydrography, engineering, and submarine geology. The vertical and horizontal distribution of the recent sediments can make a worthwhile addition to nautical charts on which bottom sediment notations appear. Sub-bottom studies will allow lines of contact between unconsolidated sediment and outcrops of bedrock to be drawn. The three most effective methods used to gain geologic data geophysically are seismic, gravimetric, and magnetic surveys. The recent development of the ship-borne gravity-meter will allow these three tools to be used simultaneously. Such a package when brought to bear on the little-known continental margins will greatly facilitate their geological interpretations and will eventually lead to the expansion of complete geologic mapping over the continental margins, making up 10 % of the continental United States, with a corresponding potential increase in the country's mineral and oil wealth.

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