conditions and (ii) after the loss of excitation of all modes except $\nu_7$.

The sound velocity is related to $C_v/R$ by the equation

$$V^2 = \frac{RT}{M}\ (1 + \frac{R}{C_v}\ ).$$

The experimental value of $C_v/R$ at low frequencies, $V_0{}^2$, and for intermediate frequencies, around 20 to 50 Mhz/atm, agree with the statistical thermodynamic predictions for cases (i) and (ii) to rather better than 1 percent.

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**Note**

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## Predation and the Origin of Tetrapods

Romer (*1*) does not take predator pressure into account as a selective force in the origin of tetrapods on the basis that ancestral tetrapods were among the largest and most powerful freshwater animals of their time. But this sidesteps the fact that young animals are usually much more vulnerable to predation than adults. Certainly, small ancestral tetrapods must have been attacked and eaten by Devonian fishes for example, the large, fast, rhizodont crossopterygians), and it seems that this could have been a strong selective force in the evolution of the tetrapod limb. Romer points out that the contemporaneous crossopterygian fishes probably were better swimmers than ancestral tetrapods. Thus, it seems logical that small ancestral tetrapods resting or searching for food in shallow water would elude their predators by scrambling out on land rather than by staying in the water; especially since, in contrast to present times, there were few if any predators on land during the Devonian. Indeed, Romer believes that (probably somewhat later on) predator pressure on aquatic amphibian eggs was strong enough to be one of the evolutionary forces behind the origin of the amniote egg. In summary, it seems possible that the evolving paired limbs of ancestral tetrapods might have given them a twofold advantage over their contemporaries: (i) a means to reach a new aquatic situation in time of drought as postulated (*1*); and (ii) a means by which the young could escape aquatic predators.

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**Reference**

1. A. S. Romer, *Vertebrate Paleontology* (Univ. of Chicago Press, Chicago, ed. 3, 1966), p. 86; *Science* **158**, 1634 (1967).

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## X-ray Fluorescence Spectrography: Use in Field Archeology

Bowman *et al.* (*1*) suggested that high-resolution semiconductor detectors in x-ray emission spectroscopy had possibilities for use in the field.

After extensive laboratory experience, a portable system was prepared to test its feasibility for site analysis on the UCLA-Israel Archaeological Expedition (1968) (*2*). The x-ray detector, cryostat, analyzer, recorder, and the auxiliary equipment (transformers, charger, batteries) were portable, and they were all hand-carried on public carriers with no special precautions. They were easily assembled on the site being investigated, whether or not electricity was available.

The method was that described by Giauque (*3*). A radioactive source, such as $^{241}$Am or $^{125}$I, is used to excite K x-rays of a selected target material, and these, in turn, excite characteristic x-rays from the sample. More than 300 separate analyses were obtained, often testing for six elements in a single 4-minute run.

The operating environments were of all sorts—from hot, dry deserts to the seacoast with its attendant high temperatures and salty humidity. The only difficulty encountered during the entire expedition was the failure of a "slow blow" fuse which was burned out by a line surge while it was operating off the local power source.

The results are only semiquantitative because of differences in texture, shape, and composition of the objects encountered. The inhomogeneity of the materials tested and the limited range of detection (only elements in the periodic table above calcium are detectable) precludes the possibility of full analysis without further preparation. This seems unnecessary for field work since the information obtained is adequate for much archeological interpretation and can be used to segregate objects worthy of more careful laboratory study.

The speed, precision, economy, and nondestructive qualities of this equipment were amply demonstrated. The particular ability of the detector to handle objects of almost any geometry without special preparation was especially significant. The objects need not be touched by either the detector or the operator.

This method of field survey is applicable to metals, glasses, glazed ceramics, and mineral specimens, but cannot give useful information on unglazed ceramics, nonmineralized rocks, and other building materials. On this particular expedition, the single largest group of artifacts analyzed consisted of glazed ceramics. After a large number had been analyzed, it became possible to develop visual criteria which were fairly reliable for identifying colorants, opacifiers, and the type of glass matrix employed.

It is now entirely feasible to analyze metals, glasses (ceramic glazes), and minerals rapidly on the excavation site. Under field conditions, accuracies of 10 to 20 percent are obtainable when elements are present in the range of 0.1 to 30 percent. The absolute errors on glazes have added uncertainty from the variability of glaze thicknesses. The sensitivity of analysis varies with the atomic number. With somewhat longer analyzing time, results can be obtained down to 100 parts (or fewer) per million for elements in the upper half of the periodic system.

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**References and Notes**

1. H. R. Bowman, E. K. Hyde, S. G. Thompson, R. C. Jared, *Science* **151**, 562 (1966).
2. J. D. Frierman, director; I. Perlman, chief physical scientist; H. R. Bowman and Carl M. York, physical scientists.
3. R. D. Giauque, *Anal. Chem.* **40**, 2075 (1968).

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