

temperature of $\approx 3.0^\circ\text{K}$. With such a low ordering temperature one might hope to break the antiferromagnetism and align the moments in an externally applied field. The results of such an experiment showed a saturation of 0.56 Bohr magnetons per Ce at 1.3°K and 50 kgauss (almost independent of field above 30 kgauss) which is in strong contrast to the paramagnetic effective moment of 2.56 Bohr magnetons expected for the trivalent Ce in the $^2F_{5/2}$ configuration, and which Paderno *et al.* find from their measurements above $\sim 150^\circ\text{K}$. The experiment suggests that 30 kgauss is sufficient to saturate a low-lying magnetic state which is split from the ground-state multiplet by the crystal field in the manner discussed by Jones (12).

In Fig. 3 we illustrate some unusual behavior of the ordering temperature of the metallic rare-earth hexaborides. The ordering temperature depends roughly upon the effective moment. We have been unable to pursue this idea further by extending the measurements to the heavier rare earths. As found by others (13), we were unable to prepare hexaborides of erbium (Er), thulium (Tm), and holmium (Ho), and, in fact, found no x-ray evidence for the existence of the former two. In addition, our terbium hexaboride (TbB_6) and dysprosium hexaboride (DyB_6) samples showed small quantities of phases other than the hexaboride. The work of Vainshtein *et al.* (5) indicates that divalent samarium (Sm) (which like trivalent

Eu would have no ground-state magnetic moment) is present in appreciable amounts in SmB_6 . In agreement, our SmB_6 showed no evidence of ordering above 1°K .

It has not yet been possible to make complete studies of variations in ordering temperature with composition. The quantitative data presented here may change somewhat if more detailed investigations on better samples are made. However, the pattern which is already emerging is likely to provide new insight and understanding of interactions between rare-earth local moments and conduction electrons.

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9. The Yb ion in our ytterbium hexaboride (YbB_6) sample is divalent as deduced from the enlarged lattice constant ($4.147 \text{ \AA}$), and previously found by others (4), as well as from the investigations of Vainshtein *et al.* (5). In agreement with this deduction and confirming the results of Paderno *et al.* our samples show no localized magnetic moment behavior at low temperatures. The earlier work of R. Benoit, *J. Chem. Phys.* **52**, 119 (1955) in which the magnetic evidence indicated the presence of trivalent Yb could not be repeated.
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11. The samples were prepared in the arc-furnace by reacting the elements during which procedure some Eu was lost by evaporation. X-ray diffraction patterns show the presence of EuB_6 and free boron. The heat capacity measurements were made by the pulse-method of F. J. Morin and J. P. Maita, *Phys. Rev.* **129**, 1115 (1963). The resistivity and susceptibility were measured using low-frequency alternating-current techniques.
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Erosion Rates Near Rome, Italy

Abstract. Before man's intensive use of the land the rates of erosion near Rome, Italy, were approximately 2 to 3 centimeters per thousand years. With intensive occupation by man the rates have increased by an order of magnitude.

Near the beginning of the Christian era, small stream valleys in the Mediterranean region began to silt up, and various works of man were buried (1). Such sedimentation, as well as that in larger valleys and estuaries, poses the question of the rates of production of sediment, past and present. I now report on present and past erosion rates in west-central Italy, especially north of Rome. For determination of these rates the loads carried by modern streams are used for averaging the modern rates of erosion over entire drainage basins. In addition, archeological sites provide rates over periods ranging up to 2500 years. Finally, lake cores provide estimates of the rates of erosion at two localities before the land was intensively used by man.

Table 1 gives stream data from four different gauging stations. The erosion rates derived for the drainage basins concerned vary between 9 and 73 cm/1000 years. These values take into consideration only the suspended load; if data for dissolved and bedload material were available, the values would be increased by an estimated 10 to 20 percent. The values (Table 1) are in general agreement with those from a study of erosion over all Italy (2).

Some archeological sites yield erosion rates over longer periods. Figure 1 illustrates one such situation; the structure served as a cistern for a Roman villa built about A.D. 150. The rough surface indicates the footings of the structure; they are made of concrete and tuff fragments originally poured into a trench. The more carefully constructed wall of bricks and shaped blocks of tuff was then built upon the footings. The soil surface at the time of construction was at the line separating the two wall textures, so that the amount of erosion here since A.D. 150 is 1.30 m. Around this structure erosion ranges between 0.60 and 1.30 m, the average rate being 50 cm/1000 years. This and six other localities are listed (Table 2), the rates of erosion varying between 20 and 100 cm/1000 years. In each of these localities man's intensive occupation of the land has always been fairly continuous.

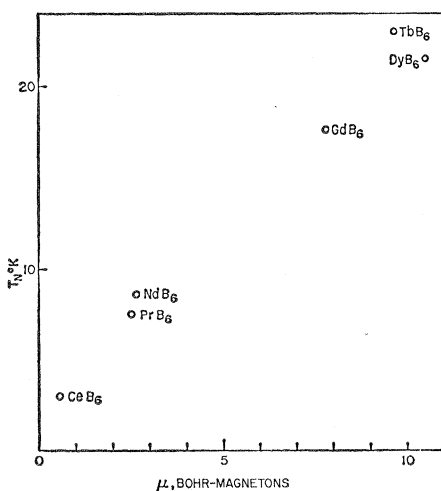


Fig. 3. Ordering temperature for antiferromagnetic hexaborides as deduced from alternating-current susceptibility and resistivity as a function of calculated effective moment, except for cerium hexaboride where the saturated (measured) moment of low temperatures is used.

Table 1. Erosion rates for some drainage basins in west-central Italy (5). The Tiber data for 1947 and 1948 are missing; differences in suspended load (and rate of erosion) between 1933-46 and 1949-64 probably reflects construction of dams after World War II; average rate between 1933 and 1946 and between 1949 and 1964 was 13 cm/1000 years.

River, station	Drainage area (km ²)	Av. annual suspended load ($\times 10^3$ tons)	Period of record (1 Jan.-31 Dec.)	Erosion rate (cm/1000 yr)
Tiber, Rome	16,545	7532	1933-46	17
Tiber, Rome	16,545	3827	1949-64	8
Tiber, Corbaro	6075	1490	1949-61	9
Ombrone, Sasso d'Ombrone	2657	1916	1954-64	29
Orgia, Monte Amiata	580	1110	1953-64	73

Table 2. Rates of erosion based on data from archeological sites near Rome. Throughout this report, depth of erosion is based on a density of 2.6 for the material transported.

Archeologic site (6)	Length of record	Nature of measurement	Bedrock, slope (deg)	Erosion rate (cm/1000 yr)
Veii	800-600 B.C. to present	Erosion over graves in Villanovan cemetery	Pleistocene tuff, 3-7	30
Villa Formello	A.D. 0-100 to present	Exposed footings of cistern	Pliocene sand and gravel, 4	30
		Exposed footings of mausoleum	Pliocene sand and gravel, 7	
Casentile	A.D. 100-200 to present	Exposed footings of cistern	Pleistocene tuff, 7	50
Casalacia	A.D. 0 to present	Exposed footings of cistern	Pleistocene tuff, 7	30
Sambuco	100-200 B.C. to present	Movement of foundations	Miocene clay and limestone, 7	40
Via Prenestina	300-100 B.C. to present	Exposed footings of road	Pleistocene tuff, 7	30
Treia	1000-450 B.C.	Sediment accumulated from known area	Pliocene clay and gravel and Pleistocene tuff, 2-90	100

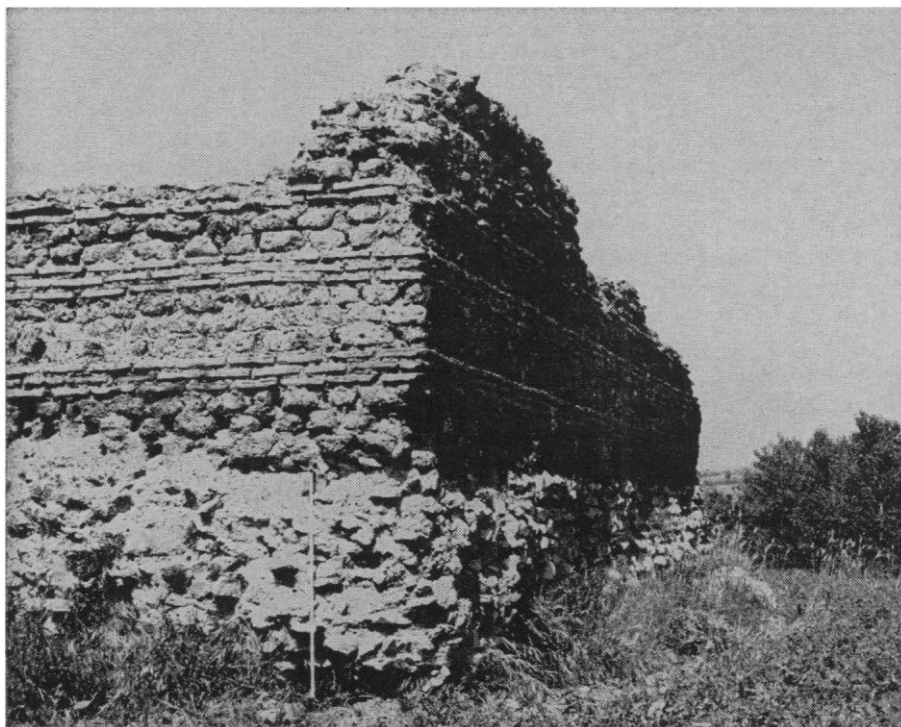


Fig. 1. Ruins of a 2nd-century A.D. cistern for a Roman villa 60 km north of Rome. The exposed footings measure 1.3 m (tape)—the amount of erosion since construction.

Some data are available on rates of erosion before man's intensive use of the land. Bonatti and Hutchinson have described cores from a small volcanic-crater lake, Lago di Monterosi, 41 km north of Rome (3). Archeological survey around the lake shows that intense human activity dates from approximately the 2nd century before Christ, when Via Cassia was constructed through the area; for this moment the cores record a sudden increase of sedimentation in the lake; the rate varies somewhat but continues high to this day. Conversion of the sedimentation rate in the lake to erosion of the watershed shows that, before intensive occupation by man during the 2nd century before Christ, the erosion rate was 2 to 3 cm/1000 years; thereafter it rose abruptly to an average of about 20 cm/1000 years.

The basin of Baccano, astride Via Cassia about 30 km north of Rome, is a volcanic crater; the lake originally filling it was drained by the Romans in about the 2nd century before Christ. Bonatti, in a pollen analysis of cores from the old lake deposits, reports a single carbon-14 age of 8429 ± 180 years (4). This date enables one to estimate the rate of sedimentation, which can be converted to rate of erosion of the watershed; the resultant estimate is about 3 cm/1000 years between about 6600 B.C. and drainage of the lake. This estimate compares closely with the low rate of erosion around Lago di Monterosi before the days of agriculture.

Thus we see that the rates of erosion in central Italy, as determined from present-day stream records, resemble determinations from archeological records extending over 2000 years and more; they vary between 10 and 100 cm/1000 years, commonly ranging between 20 and 40 cm/1000 years. These rates apply to a landscape intensively exploited by man. Before such exploitation, a much less rapid rate, 2 to 3 cm/1000 years, is indicated—lower by an order of magnitude than the rate of today or of the immediate past.

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Chrome Pyrope:

An Inclusion in Natural Diamond

Abstract. *Electron probe analyses of garnets that are rich in magnesium and that occur as inclusions in natural diamonds show that the chrome-garnet end member, $Mg_3Cr_2Si_3O_{12}$, is a major constituent (30 percent).*

The minerals that occur as inclusions in diamond are of interest because of the strong probability that they crystallized in the upper mantle. Natural diamonds have most probably crystallized within their stability field, and the high hydrostatic pressures required to form diamond can be sustained only within the mantle. This being so, inclusions in diamond are also samples of the mantle and can be expected to provide direct information on the mineralogy and geochemistry of the mantle. The inclusions might also provide information on the nucleation and growth of natural diamonds. Comparison of the chemistry of these inclusions with similar minerals in kimberlite and its associated ultramafic nodules should help in understanding the genesis of both groups.

The majority of mineral inclusions in diamonds are similar to minerals commonly found in ultramafic rocks—forsterite, enstatite, pyrope, diopside, and chrome spinel. Individual inclusions are invariably monomineralic, but occasionally several mineral species will occur as separate inclusions in one diamond; for example, olivine and garnet. The chemical compositions of several inclusions are demonstrably different from the normal kimberlite or nodule minerals, however. And a major difference is that the garnet inclusions contain up to 30 percent of the end member $Mg_3Cr_2Si_3O_{12}$, whereas the normal kimberlite garnets are considerably more aluminous.

The included garnets are generally

claret colored; and, as their indices of refraction (1.759 to 1.781) and cell edges (11.535 to 11.698 Å) lie within the corresponding ranges for the pyrope-almandine-grossular series, mistaken identification can occur if standard methods are used without recourse to chemical analyses. Unfortunately, the inclusions average 50 μ in their longest dimension, and determination of their specific gravities is not feasible.

Chemical analyses (1) were made with a Materials Analysis Company model-400 electron probe on the inclusions after their removal from the host diamond (2). The inclusions were most reliably and easily removed by burning the diamond in air at 800°C for approximately 6 hours, a treatment which did not cause any apparent change in the appearance or composition of the garnet. Standards used in the analyses were predominantly glasses prepared by J. F. Schairer and by F. R. Boyd (3). The intensity ratios from the probe were reduced to chemical analyses with the use of computer programs written for the Univac 1108 in Fortran V (4). These programs correct the initial intensity ratios for drift, dead time, background, absorption, fluorescence, and atomic number effects.

Most of the figures for the analyses quoted in Table 1 are believed to be correct to better than ± 2 percent of the amount of an element present. In the case of manganese, the CrK β peak interfered with the background under the MnK α peak, and the consequent difficulty in estimating the true background resulted in errors up to 10 per-

cent of the total amount of manganese. The ratio $\sigma/(\bar{N})^{1/2}$ (see Table 1) gives an indication of the homogeneity of the material being investigated—a number less than 3 shows no evidence of inhomogeneity. By this test the garnet inclusions show a remarkably high degree of homogeneity compared with many other minerals studied with the electron probe. Potassium is not reported in Table 1. Though present, it is minor, and analysis for potassium in garnet 1 showed a concentration of less than 100 parts per million. Since the electron probe can only determine total iron, the FeO contents were adjusted to give sufficient Fe_2O_3 to satisfy charge requirements. The percentages of oxides (by weight) in the analyses (Table 1) were first converted to corresponding number of cations on the basis of 12 oxygen ions. The ferrous ions were adjusted to give enough ferric ions to produce the correct garnet divalent to trivalent cation ratio (that is, 3:2). The adjusted cation totals were then used to calculate the percentage of each end member in a unit formula of garnet in the order given (Table 1). Because of the small calcium content there is little difference whether the chromium is first assigned to uvarovite or to $Mg_3Cr_2Si_3O_{12}$.

These chrome-pyrope garnets are the most rich in magnesium yet found in nature (5). The name Hanléite was proposed by Sir Lewis Fermor (6) for a natural garnet approximating the composition $Mg_3Cr_2Si_3O_{12}$, which was reported by Mallet (7) to occur in association with chromite and serpentinite near

Table 1. Chrome-rich pyrope garnets. Diamonds from which garnets were obtained are probably from Africa, but the exact source is unknown. Inclusions 1 and 6 are from different diamonds; 15e and 15h are separate inclusions from the same diamond. Numbers in parentheses are the ratios $\sigma/(\bar{N})^{1/2}$, where σ is the standard deviation and $\bar{N}$ is the mean count.

	Chemical analyses of garnets in terms of percentages of constituent oxides (by weight)							
	1		6		15e		15h	
SiO ₂	42.3	(3)	42.8	(2)	41.8	(3)	42.2	(2)
TiO ₂	0.02	(1)	0.00		0.02	(1)	0.02	(2)
Al ₂ O ₃	17.2	(1)	18.2	(2)	15.7	(2)	15.7	(2)
Cr ₂ O ₃	8.93	(1)	7.9	(1)	10.9	(1)	10.7	(1)
FeO*	5.36	(1)	4.75	(2)	5.71	(1)	5.57	(1)
MgO	25.3	(1)	25.5	(2)	24.2	(1)	24.5	(1)
CaO	1.09	(1)	1.35	(1)	2.19	(1)	2.22	(2)
MnO	0.21	(1)	0.17	(1)	0.20	(1)	0.19	(1)
Total	100.41		100.67		100.72		101.10	
Percentage of end members in unit formula†								
Spessartite	0.4		0.3		0.4		0.4	
Andradite‡	2.8		2.7		4.1		4.8	
Skiagite‡	1.1							
Uvarovite			0.7		1.4		0.8	
$Mg_3Cr_2Si_3O_{12}$	24.9		21.2		29.5		29.2	
Pyrope	63.9		67.7		56.2		57.0	
Almandine	6.9		7.4		8.4		7.8	

* Total Fe as FeO. † Calculated in order given (see text). ‡ Some FeO recalculated as Fe_2O_3 to satisfy charge requirements.