

per ml.) is added 0.5 ml. of 10 N sulphuric acid, 2 ml. distilled water and then 2.5 ml. 5 per cent ammonium molybdate solution (kept in a wax bottle). Add 10 ml. iso-amyl alcohol (quality used "pure for milk testing") and shake in a tap funnel for two minutes. Discard the aqueous layer and wash three times with 5 ml. N sulphuric acid, discarding the aqueous layers. Add 15 ml. of the diluted stannous chloride reagent and shake for 30 seconds. Discard the aqueous layer. Wash three times with 5 ml. of the diluted stannous chloride reagent, discarding the aqueous layers. Make up the residual blue alcoholic solution to 10 ml. with ethyl alcohol. This solution may then be compared in the colorimeter with the solution obtained from a phosphate solution of known concentration; generally, one containing 1 μ gm./ml. was used.

Preparation of Steels for Test. 1. *Ordinary steels.* Take 0.05-0.20 gm. of the steel, according to its content of phosphorus, and dissolve in a covered beaker in 2.5 ml. 1:1 nitric acid. Warming will usually be necessary to ensure complete dissolution. Heat on a water bath until no more brown fumes are evolved. Add 2.5 ml. 2.5 per cent potassium permanganate solution and boil a few minutes. Cool and add 3 per cent ferrous sulphate until a clear solution is obtained, taking care to have only a light excess of ferrous sulphate. Make up this clear solution to 50 ml. 5 ml. of this final solution is used for the phosphorus determination described above.

2. *Special steels.* The procedure is the same as is outlined above, except that it will usually be necessary to dissolve in aqua regia and to heat on the water bath until all free chlorine has been driven off. In addition, it may be necessary to use rather more potassium permanganate before a permanent precipitate is obtained.

Phosphorus content of the reagents used. Blank determinations should be made from time to time on the reagents and distilled water in use, especially when fresh batches of reagents are made up, and corrections applied for any significant phosphorus content determined. Owing to the possibility of such significant phosphorus content in the reagents, it is therefore advisable to use minimal amounts of reagents during the preliminary preparations of the steels, especially of potassium permanganate and ferrous sulphate. In this Laboratory, products of 'Analar' purity were not often obtainable.

Brass and Bronze. Good results have been obtained by dissolving in strong nitric acid, boiling until free from brown fumes, making up to standard volume and then determining the phosphorus direct on this solution.

If, however, tin is present, it is necessary to dissolve in aqua regia, take down on the water bath almost to dryness and then take up in a little hydrochloric acid, so as to obtain a clear solution. It has been observed that any precipitation due to stannic acid is accompanied by low phosphorus figures. Every effort is therefore made to retain in solution all the tin by small additions of warm hydrochloric acid, enough being added to prevent precipitation on dilution to standard volume. At the same time the addition of hydrochloric acid should be minimal and only sufficient to comply with these conditions.

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¹ *Biochem. J.* (1936).

Determination of the Age of Minerals by means of the Radioactivity of Rubidium

THE suggestion has been advanced by Goldschmidt¹ that the radioactive decay of rubidium into strontium might be utilized as a means of determining the age of minerals. Hahn and Walling² have discussed the problem and assess the half-life period of rubidium as 2.3×10^{11} years. The rubidium isotope of mass number 87, 27 per cent of which is present in ordinary rubidium, is radioactive, the generation of strontium involving the loss of only a β -particle, that is, $Rb(87) \rightarrow Sr(87) + \beta$.

Since the half-life period of the above disintegration is considerable, and because rubidium never occurs in minerals in very large quantities, only a small amount of Sr^{87} is generated and danger of contamination by ordinary strontium is considerable. In 1,000,000,000 years, a mineral containing 2.0 per cent rubidium will produce 0.006 per cent strontium. To obviate contamination so far as possible, minerals should be relatively rich in rubidium and they should belong to a type that is not likely to contain ordinary strontium in quantity.

Minerals richest in rubidium are the lithia micas (lepidolites)³ which quite frequently contain as much as 2-3 per cent Rb_2O , and although knowledge of the isotope ratios of strontium in lepidolites is almost non-existent, it is probable that only very small quantities of strontium are likely to be present. A mass-spectrographic analysis by Mattauch⁴ of a rubidium-rich mica from Canada revealed a predominance of Sr^{87} , ordinary strontium being present in negligible traces. Amazonite (green microcline) also contains relatively large quantities of rubidium^{5,6}, and although no mass-spectrographic analyses of the strontium present in amazonites are known, investigations by Filippov and Tolmačev⁷ indicate that this mineral is likely to contain ordinary strontium in quantities greater than negligible traces. The strontium contents of some specimens of amazonite of known age were determined spectrochemically by these investigators, who concluded that in each case the strontium found exceeded that generated by radioactivity. Lepidolite therefore appears to be the most suitable mineral for age determinations by means of the radioactivity of rubidium. Although no data are available for the very rare mineral pollucite (caesium aluminium silicate), an analysis⁸ of a sample from Karibib, South West Africa, revealed the presence of 0.54 per cent Rb_2O , and this mineral may also therefore be suitable for age determinations.

A synthetic standard was prepared containing a ratio of rubidium to strontium (230) corresponding to an age of 1,500,000,000 years. By means of this standard, Rb/Sr ratios of five samples of lepidolite and one of pollucite were determined spectrochemically by a method that has been developed in this laboratory, the resultant ages being as follows:

1	Lepidolite	Black Hills of S. Dakota, U.S.A.	1,330,000,000 years
2	"	Okongava Ost 72, Karibib, South West Africa	900,000,000 "
3	Pollucite	" " " "	900,000,000 "
4	Lepidolite	Albrecht's Höhe, Karibib, South West Africa	1,200,000,000 "
5	"	Omaruru, South West Africa	1,200,000,000 "
6	"	Warmbad, South West Africa	980,000,000 "

Analysis No. 1 checks almost exactly with existing age determinations from the Black Hills, while Nos. 2 and 3 check very closely with the single determination that is available (880,000,000 years)⁹ for the later phases of the Old Granite of southern Africa. No. 6 appears to be slightly high, and although Nos. 4 and 5 are of the same order of magnitude, the ages are considerably higher, thus suggesting the presence of ordinary strontium in small quantities.

Mass-spectrographic examinations of all samples are required for a final adjustment of the ages, and improvement in the precision of the spectrochemical method is desirable. Although each sample was arced in quadruplicate, errors of the order of $\pm 50,000,000$ years in 1,000,000,000 years (± 5 per cent) are not infrequent.

Although the investigation is still in its preliminary stages, the results are undoubtedly encouraging. Since both rubidium and strontium are determined spectrochemically, the method offers definite advantages of speed; including preliminary chemical treatment, the ages of about fifteen specimens can be determined in quadruplicate, in three days.

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¹ Goldschmidt, V. M., *Skr. Norske. Vid.-Akad. Math.-Nat. Kl.*, No. 4, 140 (1937).

² Hahn, O., and Walling, E., *Zeit. Anorg. u. Allgem. Chem.*, **236**, 78 (1938).

³ Ahrens, L. H., *Nature*, **155**, 610 (1945).

⁴ Mattauch, J., *Naturwiss.*, **25**, 189 (1937); **25**, 738 (1937).

⁵ Goldschmidt, V. M., Bauer, H., and Witte, H., *Nachr. d. Ges. d. Wiss. Göttingen Math.-Phys. Kl.*, **1**, No. 4, 39 (1934).

⁶ Ahrens, L. H., in the press.

⁷ Filippov, A., and Tolmačev, J., *C.R. Acad. Sci. U.R.S.S.*, **1**, No. 5, 323 (1935).

⁸ Ahrens, L. H., *Amer. Min.*, in the press.

⁹ Holmes, Arthur, "The Age of the Earth", 195 (Thomas Nelson and Sons, Ltd., 1937).

A *Lepidocyclus* Limestone from the Lower Pegu (Oligocene) of Burma

Two *Lepidocyclus* horizons are now known from Burma: one occurring in the Yaw stage (Priabonian) from which I have described *Polylepidina birmanica* Rao¹, and the other represented by a limestone occurring in the Lower Pegu (Oligocene) from which Carter² described his species *Orbitolites mantelli* var. *theobaldi*. Vredenburg³ recognized Carter's species to be *Eulepidina elephantina* Mun.-Ch.: Nothing has since been added to our knowledge of the fauna, and its age has never been satisfactorily established. Through the courtesy of Mr. E. S. Pinfold, I had an opportunity of examining a specimen of this limestone, and the results obtained are summarized below.

The Pegu system, which includes beds of Oligocene and Miocene ages, forms the central Tertiary belt of Burma, occupying the tract between the Arakan Yoma ranges and the Shan plateau. The *Lepidocyclus* limestone occurs in the lower part of the system and was correlated by Vredenburg⁴ with the Lower Nari (Stampian) of North West India. The Oligocene succession as observed by Vredenburg and Cotter⁵ is as follows:

Singu stage (with a molluscan fauna of Upper Oligocene age)	} Chattian
<i>Lepidocyclus</i> limestone (with <i>Eulepidina elephantina</i>)	
Padaung stage (with a molluscan fauna of Middle Oligocene age)	} Stampian
Shwezewa stage (with <i>Ampullina birmanica</i>)	
	Lattorian.

In the lithogenetic scheme of classification adopted by the B.O.C. geologists (Lepper⁶), all the three stages of the Oligocene are represented. The formation which contains Vredenburg's Singu fauna is named by them as Okhmitaung sandstones and these are succeeded by the Pyawbwe clays. The latter is regarded as Lower Miocene, probably Aquitanian (Evans⁷). Between the two formations, they recognize an unconformity with a well-defined palaeontological break.

The limestone examined by me comes from Tondaung (19° 25' 94" 52'), which is about twenty-two miles west of Thevetmyo. Carter's specimens were obtained from Pelkthalein, which is some six miles south of Thevetmyo. The Tondaung limestone is cream-coloured, compact, chalky in places, and made up largely of calcareous alga and larger foraminifera. The only other fossils noticed are a few corals.

The species of algae present are: *Archaeolithothamnium peguensis* sp. nov.; *Lithothamnium* aff. *fractulosum* (Kütz.); *Lithophyllum irrawaddica* sp. nov.; *Lithophyllum pretichonoides* Lem.; *Mesophyllum tondaungensis* sp. nov.; *Lithoporella quadratica* Ishijima; and *Corallina cossmanni* Lem.

The foraminifera recorded are: *Eulepidina theobaldi* (Carter) (= *Orbitolites mantelli* var. *theobaldi* Carter, 1888; = *Eu. elephantina* Mun.-Ch., 1892); *Eu. dilatata* Mich.; *Eu. formosa* Schlumb.; *Nephrolepidina sondaica* Yabe and Hanzawa; *Neph. marginata* Mich.; *Operculinoides* sp.; *Heterostegina assilinoidea* Blanckenhorn; *Cycloclypeus* sp.; *Amphistegina* sp.; and *Carpenteria proteiformis* Göes. *Spiroclypeus* and *Miogypsinidae* were not noticed.