On the distribution of purple zircon in British sedimentary rocks.

By P. G. H. Boswell, D.Sc.
Professor of Geology, University of Liverpool.

[Read June 14, 1927.]

I. *Introduction.*

By the publication of his paper on 'The source of the purple zircons in the sedimentary rocks of Scotland',[1] Dr. Wm. Mackie has done his fellow-workers on the petrology of British sedimentary rocks a signal service. He has proved that this distinctive purple (or sometimes rose-coloured) variety of zircon is relatively abundant in the Lewisian gneiss. The variety occurs usually as rounded or ovoid grains, but occasionally with crystalline form; it is often finely polished, as if by wind, and is sometimes zoned, with a darker centre, or displays colour of varying intensity; it is often definitely, although but slightly, pleochroic, and usually possesses high birefringence. These characteristics at once bring to mind grains of zircon frequently met with in sedimentary rocks and recorded by numerous other observers.[2]

Dr. Mackie noted the presence of this variety as a detrital constituent in the Moine Schists, the Eastern Quartzites and Schists, the Torridonian Sandstone (and in pebbles of grit and quartzite in that rock), the Cambrian quartzites, limestones, and dolomites from north-western Scotland, the Old Red Sandstone of Scotland, the Carboniferous rocks in a boring near Glasgow, the Millstone Grit of Yorkshire, the Permian of Dumfries, and in the *Gordonia*-beds and the Triassic and Jurassic (?) sediments near Elgin. Moreover, he found the same purplish variety in various

[1] W. Mackie, Trans. Edinburgh Geol. Soc., 1923, vol. 11, pp. 200–213. [Min. Abstr., vol. 2, p. 311.]

[2] For example, Dr. R. H. Rastall refers to 'pink zonary zircons' in the Lower Greensand (Geol. Mag., 1919, vol. 56, pp. 218, 220, &c.). Other writers in their accounts of sedimentary rocks have referred certain purple zircon-like grains to xenotime. In my own notes from 1912 onwards, I have frequently recorded a 'pink or purple zircon-like mineral'. Since the publication of Dr. Mackie's paper, the references to the purple variety of zircon have been numerous.

specimens of pre-Cambrian gneisses and in a sedimentary rock from Canada, as well as in the Transvaal banket. But not the least interesting of his observations was that the true purple zircons are not common in the northern Scottish granites, other greenish, brown, and purplish-brown varieties being predominant. He suggested that the few purple grains found may, like andalusite, sillimanite, kyanite, staurolite, and garnet, have been picked up by the granite magma.

More recently, Dr. Mackie has deduced,[1] from the occurrence of purple zircons, that the Moine Series is more ancient than the Torridonian and that the latter rocks were derived in part from the Archaean, and in part from the Moine Schists.

That purple zircon is not typical of granites will, I think, be generally agreed. There is, however, a purplish-brown variety of more frequent occurrence in igneous rocks,[2] and which is often found in sediments. I am inclined to draw a distinction between the two varieties; the notes which follow, therefore, refer only to good rose-pink or purple grains.

The presence of this almandine-coloured variety of zircon is so widespread in sedimentary rocks and the type is so characteristic of certain British stratigraphical horizons, that the following notes, made in the course of other investigations during the past fifteen years, have been collected together in the hope that they may be of interest.

II. *The Coloration.*

Attempts have frequently been made to determine the probable source of different species and varieties of well-known rock-forming minerals by noting the special characters displayed by them, but it cannot be said that such attempts have always been successful. In this connexion the papers on zircon by G. Uzielli,[3] K. v. Chrustschoff,[4] H. Thürach,[5] G.

[1] Paper in course of publication in the Trans. Edinburgh Geol. Soc. (Abstract in Geol. Mag., 1927, vol. 64, pp. 141–142).

[2] For example, Dr. A. Brammall records it in the Dartmoor granite (Min. Mag., 1923, vol. 20, pp. 27–31). Subsequent investigations have led him also to record the presence of purple zircon, but the variety is not of common occurrence, and is confined to one phase of the granite.

[3] G. Uzielli, Sopra lo zircone della Costa Tirrena. Atti R. Accad. Lincei, Roma, 1876, ser. 2, vol. 3, pp. 862–877.

[4] K. v. Chrustschoff, Beitrag zur Kenntnis der Zirkone in Gesteinen. Tschermaks Min. Petr. Mitt., 1886, vol. 7, pp. 423–442.

[5] H. Thürach, Ueber das Vorkommen mikroskopischer Zirkone und Titan-Mineralien in den Gesteinen. Verh. Phys.-Med. Gesell. Würzburg, 1884, n. ser., vol. 18, pp. 203–284.

Spezia,[1] and J. Zerndt,[2] for example, may be cited. Curiously, perhaps, none of these observers except Zerndt seems to have referred to the rose-purple variety. Uzielli dealt with the probable source of some zircons and accompanying minerals, and gave detailed descriptions of their crystallography, but the only colour he noted was bluish. The work of Chrustschoff is too well-known to need more than passing reference. He mentioned grains which were colourless ('water-clear'), dusky, or of various tints of brown and yellow. Thürach, in his well-known paper cited above, gave an account of the crystal-forms and habits, but referred only to colourless, grey, and yellow varieties. Spezia attributed the red (presumably hyacinth tint) and brown coloration of zircon to the presence of iron and not organic substances, and expressed the view that colour-change does not depend on the temperature to which zircon is heated, and that thermoluminescence ('pyrophosphorescence' as it was then called) is not related to the colour. These conclusions were contested by K. v. Kraatz-Koschlau and L. Wöhler,[3] who found that a loss of weight occurred in zircon heated in a stream of oxygen, and that carbon dioxide was found by passing the gases into lime-water. Spezia later replied (in the 1899 paper cited) to these criticisms, reaffirming his opinion that red zircon from Ceylon owed its colour to the state of oxidation of the iron present and not to organic matter, an insufficient quantity of which was present. He claimed that he had obtained an increase in the depth of colour on heating the mineral under oxidizing conditions, and a decrease on heating under reducing conditions.

A notable contribution to the literature of the colour of zircons is a more recent paper by Lord Rayleigh,[4] in which he described the effects of radio-active treatment of brown and reddish (hyacinth) varieties, the colour of which had been destroyed by heating to 300° C. Both the colour and property of thermoluminescence (which also disappears on heating) are restored by such treatment. He therefore attributed the colour to the effects of included radio-active substances.

Numerous later workers have figured types of zircon grains, and have

[1] G. Spezia, Sul colore del zircone. Atti Accad. Sci. Torino, 1876, vol. 12, pp. 37–43, and 1899, vol. 34, pp. 906–910.

[2] J. Zerndt, Über mikroskopische Zirkone aus den Karpathensandsteinen der Umgegend von Ciężkowice. Bull. Intern. Acad. Polonaise Sci. Lett., Ser. A, 1924, pp. 219–229.

[3] K. v. Kraatz-Koschlau and L. Wöhler, Die natürlichen Färbungen der Mineralien. Tschermaks Min. Petr. Mitt., 1899, vol. 18, pp. 304–333.

[4] R. J. Strutt, Note on the colour of zircons, and its radioactive origin. Proc. Roy. Soc. London, Ser. A, 1914, vol. 89, pp. 405–407.

attempted, like some of the investigators mentioned above, to refer them to sources in igneous or metamorphic rocks respectively. Others have endeavoured to show that such essays are of little value. Of late (perhaps wisely), these attempts appear to have been abandoned.

It seemed to me desirable to obtain, if possible, further information regarding the colour of the rose-purple variety, despite the difficulties involved in the small size and sporadic occurrence of the grains in sediments. To this end, special separations were made of the heavy detrital minerals from the Carboniferous Sandstone (Millstone Grit) from Glenboig, Lanarkshire, in which purple zircons are very abundant. In view of the possible confusion of brown or purple zircon with xenotime in sediments, spectroscopic examination was desirable, although Dr. Brammall had already proved that the brown zircons from the Dartmoor granite give no spectroscopic evidence of the presence of yttrium.

As I was unable to obtain with a spectroscopic attachment to the eyepiece of a microscope, a distinctive spectrum from even the most deeply-coloured purple grains, I am the more indebted to Messrs. R. W. Roberts and J. H. Hamshen of the Physics Department of the University of Liverpool for the trouble they undertook to obtain carbon-arc photographs of the absorption-spectrum of some typical purple grains. The results were negative in so far that no spectrum specially characteristic of this variety of zircon was obtained, but the failure may be attributed to the small size of the grains (0·1 to 0·2 mm. diameter). If larger crystals could be found, it would be more satisfactory to have the experiments repeated.

Dr. Mackie had already observed that the crystals of purple zircon were bleached, like other varieties of the mineral, on being heated in air to about 300° C. After treating some grains in this way (under oxidizing conditions), and rendering them colourless, I mounted a sample on a glass slip by means of an exceedingly thin smear of paraffin-wax, taking care that the grains were not covered by wax. Mr. R. W. Roberts then subjected these grains to the action of β- and γ-rays for 166 hours. The colour was partially restored, most of the grains showing a pale-pink or pale-purple tint. Presumably the duration of the treatment was insufficiently long for the restoration of the deep-purple colour.

III. *Distribution of purple zircons.*

The following notes relating to the occurrence of rose-pink or rich-purple zircon in British sediments are in no sense complete, but they may serve to stimulate investigation and lead to further recording of this variety. It is desirable also that its associated minerals, which are often themselves distinctive, should be recorded.

As the number of individual localities is very large, they have been grouped in counties or districts.

Pre-Cambrian: Moine Schists; Eastern Schists (Scotland), Eastern Quartzites (Scotland); Torridon Sandstone, Quartzites (Donegal).
Cambrian: Shropshire; north-western Scotland.
Ordovician: ?
Silurian: Llandovery Sandstone of Shropshire and Malvern district. Denbigh Grit.
Old Red Sandstone: Northern Scotland; Kincardineshire, Perthshire; South Wales, Herefordshire, Shropshire.
Carboniferous: Throughout the whole system, including Lower Limestone Series, Calciferous Sandstone, Yoredales, Pendlesides, Millstone Grit, Lower, Middle, and Upper Coal Measures. Northern Ireland; Scottish Lowlands; I. of Arran; Northumberland, Durham, Yorkshire, Derbyshire, Midlands generally, Lancashire; North Wales (including Vale of Clwyd).
Permian: Elgin *Gordonia* Beds; Scottish Lowlands, Dumfries; Lancashire, Yorkshire, Midlands.
Bunter: North-eastern Ireland; North Wales (including Vale of Clwyd); Lancashire, Cheshire, Staffordshire, Warwickshire, Worcestershire, Gloucestershire, Nottinghamshire, Derbyshire, Yorkshire.
Keuper: Midlands, Cheshire.
Lias: Midlands, Cotteswold area, Dorset.
Inferior Oolite and Estuarine Series: Cotteswolds (northern end), Northampton Ironstone generally, Yorkshire.
Callovian: Yorkshire, Northamptonshire, Brora.
Corallian: Berkshire.
Kimmeridgian: Buckinghamshire, Oxfordshire, Berkshire, Dorset, Wiltshire, Lincolnshire.
Portlandian: Buckinghamshire, Oxfordshire, Dorset, Wiltshire.
Neocomian and Wealden: Spilsby Sandstone, Carstone of Yorkshire and Lincolnshire, Weald generally.
Aptian: Lower Greensand generally. Weald; Isle of Wight; Berkshire, Oxfordshire, Buckinghamshire, Bedfordshire, Norfolk.
Albian: Devon, Wiltshire; Weald; borings through London Basin. Also Belgium.
Chalk: East of England generally.
Eocene: All divisions from Reading Beds to Bagshot Beds, London Basin throughout; Isle of Wight and Hampshire; Dorset, Devon, and Cornwall. Also Belgium.
Pliocene: Diestian generally. Red Crag, Norwich Crag, Chillesford Beds, &c.; Cornwall. Also Belgium.
Pleistocene: Glacial and fluviatile deposits throughout England and Scotland.
Recent: Shore- and Dune-sands and River-deposits generally.

Although there are certain inequalities of distribution of purple zircons in the various formations listed above, these may be expected to disappear on the completion of further work. It may also be found that formations not mentioned in the above table may prove to contain this variety of the mineral in addition to the other varieties known to be present. But there are certain British deposits in which purple zircon may be considered an abundant and characteristic constituent of the sediments and in which it is accompanied by other significant detrital minerals. Such deposits are the various divisions of the Carboniferous, Permian, and Bunter rocks, and the Lower Greensand.

In the Carboniferous rocks of Scotland and northern Ireland, purple zircons are found in great abundance, and are often of a typical deep colour and ovoid form. They are characteristic of the Carboniferous Limestone Series at Ballycastle, Caldwell, Campbeltown, I. of Arran, Monkredding, &c.; of the Upper Calciferous Sandstone Series at Coolkeeragh and Cookstown, of the Upper Limestone Series at Auchenheath; of the Millstone Grit at Blochairn, Crofthead, Drumcavil, Garngad, Garnkirk, Gartverrie, Germiston, Glenboig, &c.: and of the Coal Measures at Plean, Pordovan, Rawyards, &c.

The variety is often accompanied by abundant monazite, as at Auchenheath, Crofthead, Drumcavil, Garngad, Glenboig, Plean, Pordovan, Rawyards, or by staurolite, garnet, red rutile, chlorite, sphene, hornblende, pleonaste, and rarely kyanite. The proximity of the sediments to the ancient rocks of the Scottish Highlands leaves little doubt that all these minerals have a northern provenance. As the Millstone Grit and Coal Measures are traced southwards into Lancashire and Yorkshire, the stream of purple zircon and monazite can be followed with ease, but staurolite becomes less abundant and kyanite disappears.

Although there is a possibility of enrichment of the Midland Carboniferous rocks in monazite from Lake District or other granites, the trail of minerals of presumed Scottish provenance can be traced into Derbyshire, Warwickshire, and Staffordshire. For example, in the Millstone Grit of Biddulph Moor, monazite and purple zircon are plentiful.

In the Permian rocks of the north of England, purple zircons are by no means uncommon, their associates being monazite, staurolite, tourmaline, rutile, hypersthene, garnet, epidote, chlorite, and hornblende. Doubtless some of the Permian detrital material was obtained from older sediments, especially those of Carboniferous age, but it seems probable that some of it came direct from crystalline rocks. Thus the purple zircons of the Permian rocks of Lancashire and Yorkshire may be of 'composite' origin, but, since the grains are not so abundant as in the Carboniferous and are often of small size, these may in large part have passed through more than a single sedimentary cycle.

The purple variety of zircon may fairly be regarded as a characteristic and common constituent of Triassic sediments. It appears to be less abundant, however, in the Keuper than in the Bunter rocks. In the latter, the variety is found throughout Yorkshire, Derbyshire, and Nottinghamshire (Armthorpe, Burghwallis, Hempshill, Northallerton, Snaith, Whitley Bridge, Worksop, &c.), the Midlands (Warwickshire, Worcestershire, and Staffordshire), the Welsh borders, Lancashire, Cheshire, the Vale of Clwyd, Cumberland, Antrim, and Arran. It is often of a deep colour, of comparatively large size, and is associated with monazite, garnet, hypersthene, staurolite, sphene, hornblende, chlorite, deep-red rutile, pleonaste, epidote, and kyanite. These features suggest that it was directly derived from crystalline rocks, and not from Palaeozoic sediments.

Although purple zircon is occasionally seen in British Jurassic residues, it cannot be called an abundant or characteristic constituent. Its next re-appearance in quantity is in the Lower Greensand, where large ovoid deep-coloured and rose-pink grains are often abundant. At this horizon, also, it is accompanied by a flood of 'new' minerals, of relatively large size, the source of which cannot be placed in any British sedimentary rocks known to us. These minerals include abundant tourmaline (of varying colour and form), deep-red rutile, occasional garnets, pleonaste, sillimanite, andalusite, staurolite, sphene, monazite, chloritoid, epidote, and kyanite. Large and irregular grains of purplish-red rutile are especially noteworthy. The localities where purple zircon is plentiful are almost too numerous to mention, but they range throughout the outcrop north and south of the Weald, the Isle of Wight, Berkshire, Oxfordshire, Bedfordshire, Buckinghamshire, Cambridgeshire, and Norfolk. Again, the assemblage of minerals points to derivation from recently-exposed crystalline rocks.

Throughout the Upper Cretaceous and Tertiary strata, purple zircon is occasionally met with, but although in the Pliocene and Glacial deposits of East Anglia rich assemblages of minerals are found, the variety under consideration is neither an abundant nor typical constituent.

It is only to be expected that purple zircon should be of frequent occurrence in present-day shore- and river-sands. Large deep-coloured grains are abundant in 'concentrates' from such widely-separated localities as Montevideo, Tampico, Arkansas River, New Guinea, Senegambia, and Yunan (Korea). Many of these are from the neighbourhood of shields of Archaean rocks, which raises the question as to whether purple zircon is a widespread constituent of the latter. It will be recalled that Dr. Mackie found the variety in the Transvaal banket and the 'Laurentian' gneiss of Canada.

Summarizing, therefore, we are able to say that the purple or rose-coloured variety of zircon is especially characteristic of those British sediments in which minerals derived from regionally-metamorphosed rocks are abundant, and of 'fresh' appearance. They provide additional evidence that the deposits were formed by denudation of land-masses composed of crystalline metamorphic rocks.