

Observations and Reports (*continued*).

Paris :—Bureau des Longitudes. *Éphémérides des Étoiles de Culmination Lunaire et de Longitude pour 1896.* 4to. *Paris* 1894. The Bureau.

Washington :—Weather Bureau. *Monthly Weather Review.* October, 1894. 4to. *Washington.* The Bureau.

*March 7, 1895.*

Sir JOHN EVANS, K.C.B., D.C.L., LL.D., Vice-President and Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

In pursuance of the Statutes, the names of the Candidates for election into the Society were read, as follows :—

Allen, Alfred Henry, F.C.S.  
 Barrett, Professor W. F.  
 Barry, J. Wolfe, M.Inst.C.E.  
 Bateman, Sir Frederic, M.D.  
 Bell, Robert.  
 Binnie, Alexander Richardson,  
 M.Inst.C.E.  
 Blake, Rev. John Frederick, M.A.  
 Bourne, Professor Alfred Gibbs,  
 D.Sc.  
 Bovey, Henry Taylor, M.A.  
 Bryan, George Hartley, M.A.  
 Burdett, Henry Charles.  
 Callaway, Charles, D.Sc.  
 Cardew, Philip, Major, R.E.  
 Clowes, Professor Frank, D.Sc.  
 Collie, J. Norman, Ph.D.  
 Corfield, William Henry, M.D.  
 Downing, Arthur Matthew Weld,  
 M.A.  
 Elgar, Francis, LL.D.  
 Eliot, John, M.A.  
 Elwes, Henry John, F.L.S.

Etheridge, Robert, F.G.S.  
 Gray, Andrew, M.A.  
 Green, Professor Joseph Reynolds,  
 D.Sc.  
 Griffiths, Ernest Howard, M.A.  
 Hamilton, Professor David James,  
 M.D.  
 Harcourt, Leveson F. Vernon,  
 M.Inst.C.E.  
 Haswell, Professor William A.,  
 D.Sc.  
 Head, Henry, M.D.  
 Heycock, Charles Thomas, M.A.  
 Hickson, Sydney John, M.A.  
 Hill, George Henry, M.Inst.C.E.  
 Hinde, George Jennings, Ph.D.  
 Holden, Henry C. L., Major, R.A.  
 Howes, Professor George Bond,  
 F.L.S.  
 Kipping, F. Stanley, D.Sc.  
 Lansdell, Rev. Henry, D.D.  
 Lockwood, Charles Barrett,  
 F.R.C.S.

McClellan, Frank, M.A.	Scott, Alexander, M.A.
McConnell, James Frederick Parry, Surgeon-Major, F.R.C.P.	Stebbing, Rev. Thomas Roscoe Rede, M.A.
Macewen, Professor William, M.D.	Stewart, Professor Charles, M.R.C.S.
McMahon, Charles Alexander, Lieut.-Gen.	Stirling, William, M.D.
Mansergh, James, M.Inst.C.E.	Stuart, Professor T. P. Ander- son, M.D.
Martin, John Biddulph, M.A.	Sutton, J. Bland.
Martin, Sidney, M.D.	Tanner, Professor Henry William Lloyd, M.A.
Matthey, Edward, F.C.S.	Thomson, Professor John Millar, F.C.S.
Miers, Henry Alexander, M.A.	Trouton, Professor Frederick Thomas, M.A.
Minchin, Professor George M., M.A.	Truman, Edwin Thomas, M.R.C.S.
Mott, Frederick Walker, M.D.	Turner, Professor Herbert Hall, M.A.
Murray, George Robert Milne.	Waterhouse, James, Colonel.
Notter, James Lane, Surgeon- Lieut.-Col.	Whymper, Edward, F.R.G.S.
Oliver, John Ryder, Major-Gen., R.A.	Wilson, William E.
Pearson, Professor Karl, M.A.	Wimshurst, James.
Power, William Henry.	Woodhead, German Sims, M.D.
Preston, Professor Thomas, M.A.	Woodward, Horace Bolingbroke, F.G.S.
Purdie, Thomas, B.Sc.	Wynne, William Palmer, D.Sc.
Reade, Thomas Mellard, F.G.S.	
Roberts, Ralph A., M.A.	
Rutley, Frank, F.G.S.	
Salomons, Sir David, M.A.	

The following Papers were read:—

- I. "The Rubies of Burma and Associated Minerals—their Mode of Occurrence, Origin and Metamorphoses. A Contribution to the History of Corundum." By C. BARRINGTON BROWN, Esq., F.G.S., and J. W. JUDD, F.R.S., F.G.S., Professor of Geology, Royal College of Science. Received February 6, 1895.

(Abstract.)

This memoir embodies the results of a series of investigations which were initiated by the Right Hon. Viscount Cross, sometime H.M. Secretary of State for India, shortly after the annexation of Burma by the British Government. The researches were undertaken with a view to the determination of the value of the celebrated ruby mines of that country, and of the conditions under which the gem is found. One of the authors, Mr. C. Barrington Brown, visited

Upper Burma in 1887, and, under the auspices of the Governor-General of India—the Marquis of Ava—and with the assistance of the military and civil authorities of Burma, was enabled to make a geological survey of the district and prepare a report for the use of the Home Government. The large series of specimens collected to illustrate this report was entrusted to the other author for description, and he has prepared the portions of this memoir dealing with the petrology and mineralogy of the district.

It was in a memoir read before this Society in 1798 that the crystallised oxide of aluminium was shown by Greville to be a definite mineral species, to which he gave the name of “corundum;” while, in an appendix to this memoir, the Count de Bournon exactly determined the crystalline form of the mineral. Four years later, the last-mentioned author submitted a second paper to this Society, in which the mode of occurrence of the mineral in Ceylon and in the Salem District in Southern India was fully discussed. Twenty years later, Leschenault de la Tour, while on a scientific mission to Southern India, collected and sent to Paris a remarkable series of rocks from the gem-bearing districts. Quite recently, an able French mineralogist and petrographer, M. A. Lacroix, has described the series of specimens in the collections made by de Bournon and Leschenault de la Tour. Much light has been thrown on the mode of occurrence of the corundum in India by the labours of Mr. F. M. Mallet, Dr. V. Ball, and other members of the Geological Survey of that country; the remarkable emery deposits of Asia Minor have been thoroughly studied by the late J. Lawrence Smith and Professor G. Tschermak; while the occurrence of corundum in the Eastern States of North America has formed the subject of important memoirs by Dr. Genth and other authors.

The famous ruby district of Upper Burma was almost unknown to Europeans before the annexation of the country by the British. It is situated about 90 miles N.N.E. of Mandalay, and about 11 miles E. of the military post of Thebayetkin, on the Irrawaddy. The tract, so far as explored, is about 26 miles long and 12 broad, and lies at elevations varying from 4,000 to 5,500 feet above the sea-level. The principal mining centre in this district is Mogok, and the present workings for rubies extend over an area of 45 square miles; old workings, however, being found over an area of 66 square miles. The principal mining operations are carried on in the three valleys of Mogok, Kathay, and Kyatpyen; but there are some smaller outlying districts, in which mines were formerly worked, in the Injouk Valley, near Bernardmyo, at Wapudoung, 11 miles E. of Thebayetkin, and at Launzee, 8 miles S.W. of Kyatpyen. There is also a small tract of ruby-bearing rocks (crystalline limestones) at Sagyin, 24 miles N. of Mandalay; and it is asserted by the natives that two other lime-

stone hills, 15 miles N. of Sagyin, have yielded rubies; while old ruby workings were found in making the railway at Kauksay, 30 miles S. of Mandalay. It is also probable that ruby-bearing limestones, and the alluvial earths derived from them, may be found in portions of the adjoining Shan States. Indeed, at a point about 25 miles southward from Mogok, in the Shan State of Mainglôn, Dr. F. Noetling, of the Geological Survey of India, has found that rubies have been obtained from the alluvium of a stream that flows from the mountains that lie considerably to the S.E. of the Mogok District.

The rubellite (red tourmaline) of the same district was found by Mr. Barrington Brown not to occur in association with the rubies, but to come from certain gneisses and schistose rocks. The locality which yields this gem, so highly prized by the Chinese, is Nyoun-gouk, 10 miles S.E. of Mogok; the alluvium which yields the rubellite appears never to contain rubies and spinels. Black tourmaline (schorl) has been extensively worked, as shown by Dr. F. Noetling, in the Shan State of Mainglôn, not far from the rubellite locality.

In the mountainous tract which includes the ruby districts, the general trend of the hill ranges is from east to west. The bottom of the Mogok Valley, in which the principal workings are situated, lies at a height of 4,100 ft. above the sea; while the loftiest mountains of the range to the north and east are the Chenedoung Peak, 7,362 ft., and the Taungnee Peak 7,775 ft. above the sea-level. The alluvia of the valleys of Mogok, Kathay and Kyatpyen are formed by streams flowing southwards from this mountain chain; while those of the valleys of Injouk and Kabein are deposited by streams flowing in the opposite direction. The district, which is a somewhat malarious one, has an annual rainfall of about 80 inches; but in March, April, and May, the supply of water for mining operations is deficient.

The mountains are composed of various gneissic and granulitic rocks, occasionally passing into schists. Subordinate to the general mass of gneisses, often containing garnets, are certain peculiar varieties of foliated and massive rocks, including both acid and basic types, with limestone bands, often of a highly crystalline character. It was in these limestones that the rubies and spinels were found to be embedded, associated with graphite, phlogopite, pyrrhotite, and many other minerals. The sides of the hills are found to be shrouded in a deposit of hill-wash, often 50 ft. in thickness, composed of fragments, derived from the mountains, embedded in a clayey matrix. On the bottoms of the larger valleys there are extensive level deposits of alluvial matter, consisting of brown, sandy clay, resting on coarse gravels, which in turn cover other argillaceous beds. It is in these lower clay beds of the river alluvia, and in similar deposits formed in gullies in the hill-wash, that the rubies, spinels, and other gems of the district are found.

Mining operations for the obtaining of rubies are carried on in Burma in four different ways. (1.) In the alluvia, "twinlones," square pits from 2 to 9 ft. across, ingeniously timbered with bamboo, are sunk to the ruby earth, the drainage of the pits and the removal of material being effected by baskets attached to balance poles, both made of bamboo. (2.) In the hill-wash long open trenches, called "hmyaudwins," are carried from the sides of a gully, and the earth is washed out by streams conveyed into the trenches by bamboo pipes. (3.) In the caves and fissures filled with earth which abound in the limestone rocks, regular mines—"loodwins"—are opened, and the productive ruby earth is followed for long distances by means of shafts and galleries. (4.) The limestones which contain the rubies are at one or two points quarried, and the gems are obtained by breaking up the rock masses.

The extensive rubellite mines at Nyoungouk are worked in a somewhat similar plan to the "hmyaudwins." Water is delivered by a number of bamboo pipes at the head of the almost vertically exposed faces of alluvium; and as the masses of the latter are loosened, the miners dash water upon them from shovel-shaped baskets, and are able to detect and pick out by hand the brilliantly coloured stones exposed on the washed surfaces.

The petrology of this district of Upper Burma, in which the rubies, spinels, and rubellite occur, presents features of the greatest geological interest. In many respects the petrology of Burma exhibits close analogies with that of the corundiferous localities of Ceylon, the Salem District, and other portions of the Indian peninsula; but some of the phenomena presented by the rocks of the Burma ruby district do not appear to find a parallel in any of the gem-yielding tracts described by de Bourmon and more recently by Lacroix.

The general mass of gneissic rocks composing the mountainous district in which the ruby localities are situated are of intermediate chemical composition, and consist of biotite-gneisses, biotite-granulites, and, more rarely, biotite schists—rocks in which hornblende is rare or altogether absent, but which, on the other hand, are often remarkably rich in garnets. Neither corundum nor spinel have been certainly detected in these rocks.

Interfoliated with these ordinary gneissic rocks, which form the great mass of the mountains, we find rocks of much more acid composition, including very coarse pegmatites and graphic granites, aplites and granulites (leptynite or Weiss-stein), granular quartzites, and orthoclase-epidote rocks. The orthoclase of these rocks frequently contains inclusions of fibrolite and other minerals, it often exhibits the "murchisonite" modification and partings, and is not unfrequently converted into "moonstone;" still more complete alterations of the orthoclase into epidote, muscovite, and kaolin being by

no means uncommon. In the rubellite district of Nyoungouk these acid rocks contain pink and blue tourmaline (rubellite and indicolite), often beautifully zoned, and it is probably from rocks of this class that the fine gem rubellites are derived.

Of still greater interest are certain other subordinate rocks of basic and sometimes ultra-basic composition. These include the remarkable pyroxene-gneisses and pyroxene-granulites, which have in recent years been described as occurring in so many widely-scattered regions—such as Ceylon, Southern India, Central and Southern Europe, Norway and Sweden, Brittany, Spain, Algeria, Eastern, Western, and Southern Africa, the United States and Canada, Brazil, and New Caledonia. In these rocks the feldspars are for the most part basic ones, near to anorthite; the crystals almost always exhibit the phenomenon described by French petrographers as “quartz of corrosion,” and the partial or complete transformation of these feldspars into scapolite (“werneritisation”) can frequently be traced. The ferro-magnesian silicates are represented by many varieties of augite (sahlite, diopside, and ægerine), of enstatite (bronzite and hypersthene), and more rarely of hornblende. Garnets are a frequent and abundant constituent in many of these rocks, which, in their accessory minerals and their structures often exhibit many features of striking interest. By the gradual disappearance of the feldspars from these rocks, they pass into remarkable varieties of pyroxenites and amphibolites. The chief varieties of these rocks, which are now described from Burma, are the following:—Augite-gneiss (with sahlite, green diopside, &c.), augite-granulites (very rich in garnet), enstatite-gneiss (with bronzite or hypersthene), enstatite-granulites (rich in garnet), scapolite-gneisses, scapolite-granulites, pyroxenites and amphibolites of many varieties, and lapis-lazuli (lazurite-diopside-epidote rock). Many of these rocks contain crystals of calcite scattered through them.

It is with these basic rocks, and more especially with the ultra-basic types last mentioned, that the remarkable crystalline limestones that contain the rubies and spinels are most intimately associated; indeed the passage of rocks consisting of various silicates with a few calcite crystals into masses principally composed of calcite, but with the silicate minerals and oxides dispersed through them, is of the most insensible kind. Some of the ruby-bearing limestones are highly micaceous (“cipollinos”), others are “calciphyres,” in some of which the individual calcite crystals attain enormous dimensions. With the rubies and spinels are found a great number of oxides and silicates, both original and secondary, with much graphite and pyrrhotite.

In the gravels and clays of the district fine specimens of the minerals derived from the atmospheric degradation of the limestones and

other rocks are found, sometimes broken and waterworn, at other times almost uninjured.

The study of the extensive series of minerals brought from the ruby mines of Burma is calculated to throw light upon many important scientific problems.

The association of minerals in the remarkable crystalline limestones of Burma is worthy of the most careful consideration. Corundum—in its various forms of ruby, sapphire, white sapphire, oriental amethyst, oriental topaz, &c.—is found associated with red, purple, brown, black and other spinels, the relative proportions of the minerals composed of aluminium oxide and of magnesium aluminate being very variable. The other minerals present in the crystalline limestones are zircon (rare); garnets (abundant in some places); a remarkable blue apatite; feldspars, of many species and varieties (including murchisonite, moonstone, sunstone, &c.), and in every stage of alteration; quartz (in many varieties, and exhibiting some remarkable peculiarities of crystallisation); micas (phlogopite, fuchsite, with muscovite and other secondary and so-called hydromicas); hornblende and arfvedsonite; augite (sahlite, diopside, and ægyrine); enstatite (bronzite and hypersthene); wollastonite; lapis-lazuli; fibrolite; scapolite; with graphite and pyrrhotite. In addition to muscovite and other secondary micas, we find the following alteration products:—Diaspore, margarite, and other clintonites, chlorites, vermiculites, and carbonates.

It is a noteworthy circumstance that none of the silicates combined with fluorine and boron compounds—such as topaz, tourmaline, chondrodite and humite, axinite, or datholite have been certainly detected in these limestones. Beryl (aquamarine) and danburite have been said to occur in the ruby earths, but there is reason for doubting the correctness of the statement. The limestone which, in the association of minerals found in it, most closely resembles the rock of Burma, is the remarkable white limestone of Orange County, N. Y., and Sussex County, N. J.; but in the American rock the corundum and spinels are associated with tourmalines and chondrodites.

In considering the question of the *origin* of the corundums and spinels of Burma, there are several very important facts to be borne in mind. The gems, when found *in situ*, always appear to occur in the limestone, and this limestone is of a very remarkable character. There are no facts which point to the conclusion that the limestone was originally of organic origin, but many circumstances suggest that it may have been formed by purely chemical processes going on at great depths within the earth's crust. The highly-crystalline calcareous rock, besides containing so many silicates and oxides, is associated in the most intimate manner with pyroxene-gneisses and

granulites containing anorthite, and with various pyroxenites and amphibolites. The lime feldspars and lime-soda feldspars of these rocks show the greatest tendency to undergo change—passing into scapolites by the process known as “werneritisation,” and eventually giving rise to the separation of calcium carbonate and hydrated aluminium silicates. That from the last-mentioned salts the hydrated oxides of aluminium (diaspore, gibbsite, bauxite, &c.) may be separated has been shown by the studies of Liebrich and others, while the conversion of these substances into the anhydrous aluminium oxide has been shown to take place by H. St. Claire Deville, Stanislas Meunier, and others.

Crystallised aluminium oxide (corundum) has now been formed by chemists by no less than 20 different processes, and in some cases, like those described by Senarmont, Weinschenk, Bruhns, and Friedel, the formation and crystallisation of the substance has been effected at very moderate temperatures under pressure. By one or other of these or similar methods, it is probably that the formation of the Burma corundum and spinel has been effected, the source of the minerals being the decomposition products of basic and easily-altered lime feldspars in the pyroxene-gneisses.

Of still greater interest than the question of the origin of the corundums and spinels are the problems connected with the remarkable changes that these minerals undergo in deep-seated rock masses. The rubies of Burma, when found *in situ* in the limestones, are usually seen to be enveloped in a mass of materials produced by the alteration of their superficial portions. Nearest to the unaltered gem is a zone of diaspore—the hydrated aluminium oxide—and this is found to pass insensibly into various hydrous aluminous silicates—margarites and other clintonites, vermiculites, muscovites, kaolinites, &c. While, in some instances, the corrosion of the rubies appears to have gone on in a seemingly irregular manner, in the majority of cases a very definite mode of metamorphosis may be detected by the study of the various examples. There are evidently certain planes of “chemical weakness” (analogous to the cleavage planes, gliding planes, and other directions of physical weakness) along which decomposition goes on most readily. The principal of these solution planes is the basal plane, and parallel to it we find the gems eaten away in a series of step-like surfaces. Other less pronounced planes of chemical weakness exist parallel to the prism faces. Unaltered corundum is, like quartz, destitute of true cleavage, and breaks with a perfectly conchoidal fracture. If, however, gliding planes and lamellar twinning be developed in corundum (like those so easily produced in the same way in calcite), parallel to the fundamental rhombohedron of the crystals, then these gliding planes become “solution planes,” along which chemical action takes place most readily. Along the



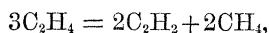
primary or secondary solution planes, hydration of the aluminium oxide takes place, and diaspora is formed, as shown by Lawrence Smith and Genth, and this unstable mineral enters into combination with silica and other oxides present to give rise to the numerous pseudomorphs of corundum, which are so well known to mineralogists.

There are certain crystals of corundum and spinel from Burma, which present illustrations of corrosion of a very remarkable and interesting character. Commencing with the formation of naturally etched figures ("Verwitterungsfiguren") the work of corrosion goes on till the whole crystal is broken up into an aggregate of simple forms—these being, in the case of the spinel, the octahedron, and in the case of the corundum, a combination of the rhombohedron, basal plane, and prism.

It is interesting to note that the quartz, feldspars, and other minerals associated with the rubies and spinels of Burma, exhibit phenomena of external etching and internal chemical change similar to those we have been describing in the case of the gems. The study of the whole of the phenomena throws much new light on the remarkable changes which take place, at great depth in the earth's crust, in minerals which, at the surface, appear to be of a very stable character.

II. "The Action of Heat upon Ethylene. II." By VIVIAN B. LEWES, Professor of Chemistry at the Royal Naval College, Greenwich. Communicated by Professor T. E. THORPE, F.R.S. Received January 10, 1895.

In a paper communicated to this Society in the spring of 1894,\* I showed that ethylene, when subjected to heat, was converted into acetylene and methane, according to the equation



and that the acetylene so formed either at once polymerised, forming a large number of secondary products, or else decomposed to carbon and hydrogen, according to the temperature at which the action was being carried on.

The fact that ethylene is one of the principal products in many cases of destructive distillation, renders a knowledge of the conditions affecting these changes of considerable importance, and the experiments described in this paper were made with the view of ascertaining the effect of rate of flow, area of heated surface, and dilution upon the changes taking place.

\* 'Roy. Soc. Proc.,' vol. 55, p. 90.