PROCEEDINGS

OF THE

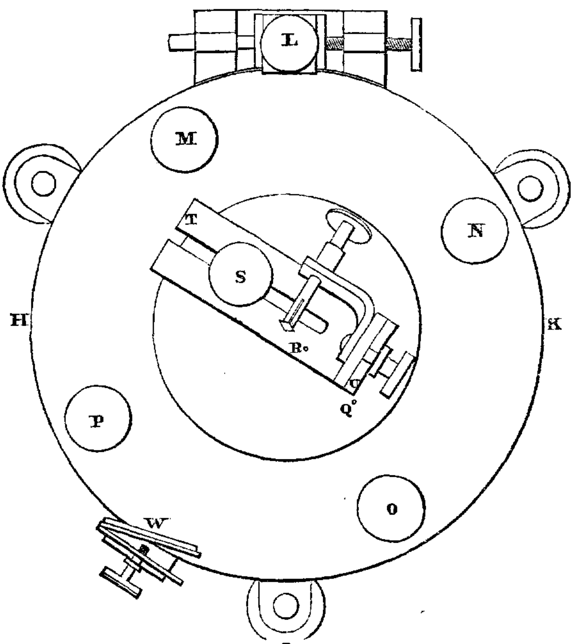
CRYSTALLOLOGICAL ASSOCIATION.

I. *On a new Form of the Reflective Goniometer.* *By* W. H. MILLER, *M.A., F.R.S., Fellow of St. John's College, and Professor of Mineralogy in the University of Cambridge* *.

AFTER the publication of a description of Mitscherlich's Goniometer (*Berlin. Abhandl.* 1843, p. 189), and of those employed by Babinet, Haidinger, v. Lang and Schrauf, an account of any other modification of this instrument may appear very superfluous. I believe nevertheless that it is possible to eliminate some sources of error, and to render the observations more accurate than with the other reflective goniometers in ordinary use, and in some instances to obtain the means of making observations otherwise impracticable. Besides, the construction of the new form is simple, and does not demand any great nicety of workmanship, except of course in the graduation of the circle and verniers. The instrument, made by Messrs. Troughton and Simms, has for its support a tripod with levelling-screws, carrying a fixed disk 200 millims. in diameter and 5 millims. thick, tapped for screws at the points D, E, F, G—by which supports for the vertical mirror, telescope, &c. mentioned later on can be attached to the instrument,

* Read June 14, 1876.

in a circle concentric with the disk, having a radius of 88 millims., the diameters through those points making angles of 45° and 32° with a fixed diameter of the disk. The graduated circle, also 200 millims. in diameter and 8 millims. thick, is divided on its edge into spaces of 20′ each, the degrees being numbered up to 360°, is read off to 20″ by each of two verniers H, K attached to the circular plate, and is provided with a clamp and slow-motion at L. It is tapped for screws at the points M, N, O, P distant 90° from one another, and about 19 millims. from the edge of the circle. A circular disk, 100 millims. in diameter and 8 millims. thick, is tapped for



screws at the points Q, R, S, 38, 13, 25 millims. distant from the centre, for securing the crystal-holder to the instrument in a convenient position. This disk is capable of revolving round a pin the ends of which enter holes in the centres of the disk and graduated circle. A rectangular piece of metal T U, having each arm 95 millims. long, 30 millims. wide and 5 millims. thick, with slits the width of which is very little larger than the diameter of the screw, can be securely clamped to the disk by a screw passing through the slit in the horizontal arm. A bar in which are inserted two screws, by which it can be secured to the vertical branch of T U, carries at its upper end the ordinary Wollaston's branch, to which the crystal is secured by a cement employed by Wollaston, consisting of beeswax melted with a little olive-oil, honey, and lampblack, and stirred while cooling to prevent the separation of the components. The crystal being now adjusted above every part of the instrument, about 195 millims. above the plane on which it rests, is brought into the axis by making T U slide and revolve. The screw being now tightened, the crystal revolves with the circle without any danger of the small angular displacement which is liable to occur, according to Dauber (Poggendorff's *Annalen*, vol. ciii. 1858, p. 107), in the best constructed goniometers when the circle is vertical and the adjustment is by sliders in grooves making right angles with one another. This method of bringing the crystal into the axis of the circle can also be applied with advantage to the small Wollaston's goniometer.

The image of the bright signal is much more distinct when the incidence is as direct as possible, more especially when the face under observation is striated or partially coated with any foreign matter. A small angle of incidence is hardly obtainable with a vertical circle or with a horizontal circle in most localities, as long as the faint signal is seen directly.

Instead of employing an object seen directly for the faint signal, it was suggested independently by A. F. E. Degen (Poggendorff's *Annalen*, vol. xxvii. 1833, p. 557) and E. Sang (Edinb. New Phil. Journ. vol. xxii. 1837, p. 213) that the image of a line seen by reflexion in a mirror could be employed for the faint signal. They failed, however, to obtain the greatest advantage from the employment of the mirror; for though theoretically correct, this is practically inconvenient, because the brightness of the reflection in the mirror very commonly extinguishes the reflected image in the face of the crystal. A better mode of procedure is to place a screen with a narrow vertical slit covered on the side furthest from the observer with thin paper, making at the crystal an angle of from 3° to 5° with the bright signal, and adopting the image of this in the dark glass mirror W for the faint signal. The mirror, about 40 millims. wide and 30 millims. high, is cemented to a thin metal plate bent so as to make an angle of about 30°, while by means of a screw tapped in the other part it can be fastened to the upper end of a strip of brass 208 millims. long, 25 millims. wide and 3 millims. thick, having slits at each end to receive screws, and bent at right angles at a point 40 millims. from the lower end.

By making the mirror revolve through a small angle round the screw which fastens it to its support, and the support round the screw by which it is fastened to the instrument, the mirror is capable of suitable adjustment. A second mirror and support will be found useful, the two mirrors being attached on opposite sides of a vertical plane passing through the centre of the instrument and the source of light. A mean of the results will be free from the errors depending upon the first powers of the eccentricity. For various reasons the accuracy of the observation increases when the angle of incidence of the light on the crystal is small. This angle can be easily reduced to less than 15°.

The accuracy of the observations is undoubtedly increased by the use of collimators; they also allow the observation to be made when the space at the observer's disposal is very limited. They may have object-glasses of from 20 millims. to 30 millims. aperture and 500 millims. or more focal length. The two collimators are mounted on supports having each three nearly* equidistant notches, so that one resting in the middle notch of each support may have its axis passing through the axis of the goniometer at a distance of 132 millims. above the plane of the graduated circle: it has in its principal focus a vertical adjustable slit, through which the light of the sun is thrown from a heliostat-mirror in the direction of the axis of the collimator. It is sometimes convenient to place a lens in front of the slit in order to enlarge the emergent pencil of light. The other collimator, resting in either pair of the corresponding notches, may have its axis passing nearly through the middle of the dark glass mirror. The end opposite to the object-glass is covered with a plate of glass ground rough on the outer surface, and covered on the inner surface with indian ink scratched away in a vertical diameter.

When the crystal is large, or is implanted on a matrix of some considerable weight, it is obviously impossible to secure and adjust it on the ordinary Wollaston's branch. In such cases it is fixed in a sort of vice having three parallel claws, one of which is movable. By screwing up this claw the crystal is secured, and then adjusted by making the vice revolve round one or the other of its two axes, making right angles with one another. Also the distance between the faces under observation may be greater than the aperture of the small telescope. The difficulty arising from this circumstance may be overcome by interposing a plate of glass mounted so as to be adjustable in azimuth and zenith-distance, supported by a stem secured to the under plate of the instrument. The observation is made by bringing the image of A seen by reflexion in the face of the crystal into coincidence with the image of the signal B seen by reflexion in the vertical plate of glass.

A small telescope having a power of about 3 may be applied, either for the purpose of observing with greater precision the coincidence of the image of A, as seen by reflexion in a face of the crystal, with the signal B or its image, or of bisecting the reflected image of signal A with the vertical spider line. The telescope is attached to an upright support, the foot of which is fastened to the upper surface of a strip of brass bent twice at right angles in opposite directions, the upper surface of the brass plate being in the plane of the upper surface of the graduated circle, and secured by a screw to the under surface of the base-plate.

By attaching the upright stem of the telescope by one of the screws to the graduated circle, the telescope becomes available for measuring the minimum deviation of a ray of any colour through two inclined faces of a crystal.

The best bright signal is the light of the sun reflected from the mirror of a heliostat through a slit so adjustable that the middle of it remains fixed in space while its diameter admits of being varied. An image of the sun in the focus of a lens of about 30 millims. focal length, formed by the light reflected from a plane mirror, is sufficient in most cases. Much inferior to these is the light of a lamp or that of the sky reflected by a plane mirror through a small opening in a screen. It is hardly necessary to remark that perfect distinctness of vision of the signals, which should be equidistant from the centre of the instrument or very nearly so, is essential to accuracy. When the eye of the observer is not adapted to the distance of the signals, the use of a Galileo's telescope of low power will greatly increase the accuracy of the result.

II. *Memoir on the three Types of Humite. By* Professor A. Des Cloizeaux, *F.R.S., Membre de l'Institut**.

Scacchi (Pogg. *Ann.* Ergänzungsb. iii. 1851) and vom Rath (Pogg. *Ann.* Ergänzungsb. v. 1871) have referred the different forms of Humite to three types belonging to the orthorhombic system, all reducible to the same elements. An examination of the optical characters, however, has led me to separate the three types, and to transfer the crystals belonging to types II. and III. to the clinorhombic system, as shown in the following pages.

* Read June 14, 1876.

Type I. System orthorhombic, with a prism-angle of 130° 19′.

$a : b : c :: 907497 : 420059 : 1849650.$

Scacchi's symbols.	Symbols of Des Cl.	Miller's symbols.	Calculated angles.	Observed angles. Scacchi.
A : B	$p g^1$	0 0 1 : 1 0 0	90° 0′	90° 0′
A : e	$p e^{\frac{5}{2}}$	0 0 1 : 2 0 5	140 49	140 47
A : e^2	$p e^2$	0 0 1 : 1 0 2	134 27	134 30
A : e^3	$p e^{\frac{3}{2}}$	0 0 1 : 2 0 3	126 21	126 17
A : e^4	$p e^1$	0 0 1 : 1 0 1	116 8	116 13
A : e^5	$p e^{\frac{1}{2}}$	0 0 1 : 2 0 1	*103 47	103 47
A : i	$p a^5$	0 0 1 : 0 1 5	138 38	138 41
A : i^2	$p a^3$	0 0 1 : 0 1 3	*124 16	124 16
A : i^3	$p a^1$	0 0 1 : 0 1 1	102 48	102 50
A : r	$p b^{\frac{5}{2}}$	0 0 1 : 1 1 5	135 52	135 48
A : r^2	$p b^2$	0 0 1 : 1 1 4	129 30	129 32
A : r^3	$p b^{\frac{3}{2}}$	0 0 1 : 1 1 3	121 44	121 44
A : r^4	$p b^1$	0 0 1 : 1 1 2	112 24	112 23
A : r^5	$p b^{\frac{1}{2}}$	0 0 1 : 1 1 1	101 39	101 41
A : o_2	$p m$	0 0 1 : 1 0 0	90 0	90 0
B : o	$g^1 g^2$	1 0 0 : 3 1 0	144 14	144 11
	$g^1 g^3$	1 0 0 : 2 1 0	132 48	
B : o_2	$g^1 m$	1 0 0 : 1 1 0	114 50	114 48
A : n	$p e_{\frac{1}{3}}$	0 0 1 : 2 1 3	116 34	116 30
A : n^2	$p e_3$	0 0 1 : 2 1 1	99 28	99 28
	$p g^3$	0 0 1 : 2 1 0	90 0	90 0 D.
	p N	0 0 1 : 2 1 2	108 26	108 20 D.

N$(=b^1 b^{\frac{1}{3}} g^{\frac{1}{2}})$ and g^3 observed by vom Rath and myself.

$e_3(=b^1 b^{\frac{1}{3}} g^1)$ and $e_{\frac{1}{3}}(=b^1 b^{\frac{1}{5}} g^{\frac{1}{3}})$ are the x and μ of figure 227 of my 'Manual of Mineralogy.' I have placed the obtuse angle of the prism in front, in accordance with the general usage for orthorhombic prisms; and I have multiplied the old value of the vertical axis by $\frac{7}{4}$ to simplify the symbols.

The plane of the optic axes is parallel to the base; the acute bisectrix is positive, and is normal to $h^1(0\,1\,0)$. Dispersion hardly appreciable in oil, $\rho < v$ (?). $2H_{a.r} = 78° 18′$ to 79°.

The laminæ parallel to h^1 consist of plates (of greater or less extent) in which the extinction of the light is complete. These are intersected by patches of irregular form in which the extinction is imperfect, and which probably consist of Humite belonging to the third type. These probably interfere with the accurate determination of the chemical composition of crystals of the first type.

Type II. Yellow Humite from Vesuvius, and brown chondrodite from Sweden (Kafveltorp).

Oblique ; prism-angle = 52° 2′ 40″.

$b : a : c :: 419122 : 907930 : 696136.$

Scacchi's symbols.	Symbols of Des Cl.	Miller's symbols.	Calculated angles.	Observed angles. Scacchi.	*Supplementary column.
A : C	$p\,g^1$	0 0 1 : 0 1 0	90° 0′	90° 0′	90° 0′
	$p\,e^2$	0 0 1 : 0 1 2	141 51	141 49 Scach. 141 48 Des Cl.	141 50
e^2 pointed out by Scacchi ; refound by vom Rath and myself in chondrodite.					
A : i	$p\,e^1$	0 0 1 : 0 1 1	*122 29	122 29	122 28
A : e	$p\,a^1$	0 0 1 : $\bar{1}$ 0 1	136 0	135 58	135 57
A : e'	$p\,o^{\frac{1}{2}}$	0 0 1 : 2 0 1	135 56	135 58	135 57
	$p\,a^{\frac{2}{3}}$	0 0 1 : $\bar{3}$ 0 2	119 56		119 52
	$p\,o^{\frac{1}{6}}$	0 0 1 : 6 0 1	119 50		119 52
$o^{\frac{1}{6}}$ and $a^{\frac{2}{3}}$, vom Rath.					
A : e_2	$p\,a^{\frac{1}{2}}$	0 0 1 : $\bar{2}$ 0 1	109 5	108 58	109 1
A : e'_2	$p\,h^1$	0 0 1 : 1 0 0	*108 58	108 58	*109 1
A : m	$p\,a_2$	0 0 1 : $\bar{3}$ 1 2	115 1	115 0	114 58
A : m^2	$p\,\beta$	0 0 1 : $\bar{3}$ 1 1	95 22	95 20	95 19
A : n	$p\,\eta$	0 0 1 : $\bar{2}$ 1 2	125 5	125 5	125 2
A : n^1	$p\,o_3$	0 0 1 : 2 1 1	125 2	125 (nearly) DesCl.	125 2
o_3 and η holohedral in Humite (v. Rath) and in chondrodite (Des Cl.).					

* See Supplementary Note, page 13.

Table (*continued*).

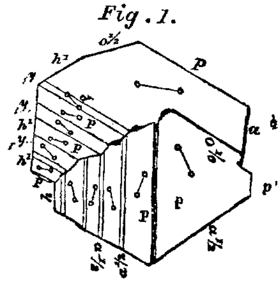
Scacchi's symbols.	Symbols of Des Cl.	Miller's symbols.	Calculated angles.	Observed angles. Scacchi.	*Supplementary column.
$A:n^2$	$p\,a_3$	$001:\bar{2}11$	103° 12′	103° 12	103° 9′
$C:n^2$	$g^1\,a_3$	$010:\bar{2}11$	135 40	135 41	135 41
$C:n^{2\prime}$	$g^1\,h^3$	$010:210$	*135 41	135 41	*135 41
$A:r$	$p\,b^1$	$001:\bar{1}12$	135 20	135 18	135 19
$A:r'$	$p\,d^{\frac{3}{4}}$	$001:223$	135 19	136 (nearly) Des Cl.	135 19
b^1 and d holohedral in Humite (v. Rath) and in chondrodite (Des Cl.).					
	$p\,b^{\frac{3}{4}}$	$001:\bar{2}23$	125 52		125 50
$A:r^2$	$p\,d^{\frac{1}{2}}$	$001:111$	125 50	125 52	*125 50
$b^{\frac{3}{4}}$ and $d^{\frac{1}{2}}$ holohedral in Humite (v. Rath).					
$A:r^3$	$p\,b^{\frac{1}{2}}$	$001:\bar{1}11$	113 28	113 28	
	$p\,d^{\frac{1}{4}}$	$001:221$	113 25	113 10 (nearly) D.	113 26
$b^{\frac{1}{2}}$ and $d^{\frac{1}{4}}$ holohedral in Humite (v. Rath) and in chondrodite (Des Cl.).					113 26
$A:r^4$	$p\,m$	$001:110$	98 12	98 18	98 13

$a_2=\alpha=(b^1 b^{\frac{1}{2}} h^1)$, $\beta=(b^{\frac{1}{2}} b^{\frac{1}{4}} h^1)$, $\eta=(b^1 b^{\frac{1}{3}} h^{\frac{1}{2}})$; $a_3=(b^1 b^{\frac{1}{3}} h^1)=\rho$, of which a part $=h^3$, are shown in fig. 228 of my ‘Manual.’

The plane of the optic axes is inclined from behind forward (from a^1 towards $o^{\frac{1}{2}}$), and makes an angle of about 30° with the base. In chondrodite the twins are of a more or less complex character, and consist of two individuals composed of laminæ twinned round an axis normal to the base, which extinguish the light well. The laminæ of the two component crystals are associated along undulating surfaces, which cannot be referred to either of the two planes adopted by Scacchi.

The accompanying figure shows one of the crystals observed by me.

Fig. 1.



The number and extent of the twin laminæ are different in each specimen; but all obey the same law of association.

The acute bisectrix is positive and normal to the plane of symmetry.

$2H_{a.r}=86°\ 27'$.

$2H_{a.b}=86°\ 38'$; $\rho<v$, weak.

* See Supplementary Note, p. 13.

Dispersion *tournante* is fairly distinct, when seen in oil, especially in pale yellow crystals. Seven thin laminæ of a more or less deep reddish brown showed the dispersion in a manner more or less marked; and the separation of the axes in oil varied for red rays from 86° 14′ to 87° 20′.

Type III. Pale yellow and white Humite from Monte Somma.
Oblique, with a prism-angle of 50° 24′.
$b : a : c :: 419575 : 907720 : 605135$.

Scacchi's symbols.	Symbols of Des Cl.	Miller's symbols.	Calculated angles.	Observed angles.
			° ′ ″	° ′
A : c	$p g^1$	001 : 010	90 0	90 0
A : i	$p e^{\frac{3}{2}}$	001 : 023	136 38	136 35
A : i^2	$p e^1$	001 : 011	*125 13	125 13
A : i^3	$p e^{\frac{1}{2}}$	001 : 021	109 26	109 30
	$p a^{\frac{5}{4}}$	001 : $\bar{4}$05	149 48	
	$p o^1$	001 : 101	149 48	
o^1 and $a^{\frac{5}{4}}$ found holohedral (v. Rath).				
A : e	$p a^1$	001 : $\bar{1}$01	143 12 30	143 15
	$p o^{\frac{3}{4}}$	001 : 403	143 11 0	
a^1 and $o^{\frac{3}{4}}$ holohedral (v. Rath).				
A : e^2	$p a^{\frac{3}{4}}$	001 : $\bar{4}$03	133 40	133 44
A : $e^{2\prime}$	$p o^{\frac{1}{2}}$	001 : 201	133 40	133 44
A : e^3	$p a^{\frac{1}{2}}$	001 : $\bar{2}$01	119 48	119 50
	$p o^{\frac{1}{4}}$	001 : 401	119 48	
$o^{\frac{1}{4}}$ and $a^{\frac{1}{2}}$ holohedral (v. Rath).				
A : e^4	$p a^{\frac{1}{4}}$	001 : $\bar{4}$01	100 49	100 48
A : $e^{4\prime}$	$p h^1$	001 : 100	*100 48	100 48
A : m	$p \alpha$	001 : $\bar{6}$23	114 55	114 46
A : m^2	$p \gamma$	001 : $\bar{6}$21	92 58	92 50
A : n	$p \epsilon$	001 : $\bar{2}$12	132 14	132 7
	$p \epsilon'$	001 : 423	132 12	
ϵ' and ϵ holohedral (v. Rath).				
A : n^2	$p \lambda$	001 : $\bar{4}$23	122 57	123 0
	$p o_3$	001 : 211	122 56	
λ and o_3 holohedral (v. Rath).				
A : n^3	$p a_3$	001 : $\bar{2}$11	111 15	111 18
A : $n^{3\prime}$	$p \pi'$	001 : 421	111 14	111 18
	$p \zeta$	001 : 14,10,3	105 43	
ζ, new form (v. Rath).				

Table (*continued*).

Scacchi's symbols.	Symbols of Des Cl.	Miller's symbols.	Calculated angles.	Observed angles.
$A : n^4$	$p\,\omega$	$001 : \bar{4}21$	97° 23′	97° 25′
$A : n^{4\prime}$	$p\,h^3$	$001 : 210$	97 23	97 25
$A : r$	$p\,b^1$	$001 : \bar{1}12$	140 14	140 20
$A : r^2$	$p\,d^{\frac{3}{4}}$	$001 : 223$	136 9	136 8
$A : r^3$	$p\,b^{\frac{3}{4}}$	$001 : \bar{2}23$	131 23	131 25
$A : r^4$	$p\,d^{\frac{1}{2}}$	$001 : 111$	125 47	125 50
$C : r^4$	$g^1 d^{\frac{1}{2}}$	$010 : 111$	137 25	137 28
$A : r^5$	$p\,b^{\frac{1}{2}}$	$001 : \bar{1}11$	119 17	119 20
$A : r^6$	$p\,d^{\frac{1}{4}}$	$001 : 221$	111 49	111 53
$A : r^7$	$p\,b^{\frac{1}{4}}$	$001 : \bar{2}21$	103 31	103 37
$A : r^8$	$p\,m$	$001 : 110$	94 35	94 28
$C : r^8$	$g^1 m$	$010 : 110$	*154 48	154 48

α, γ, ϵ, λ, $a_3 = \pi$ posterior, $\pi' = \pi$ anterior, are represented in fig. 229 of my 'Manual;' ζ, ϵ', o_3, and ω are new forms found by vom Rath.

Plane of the optic axes inclined *from behind forward*, making an angle with the base of about 11°. The acute bisectrix is positive and normal to the plane of symmetry. Dispersion of the axes very weak, $\rho < v$. Dispersion *tournante* hardly appreciable in the most homogeneous plates.

$2\,H_{a.r} = 84° 38'$ to $85° 4'$ in white crystals,

$86° 40'$ to $87° 14'$ in a yellow crystal from Monte Somma.

Internal structure more or less complex, formed by the union parallel to the base of twin laminæ (figs. 2 and 3). These

Fig. 2.

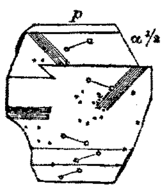


Fig. 3.

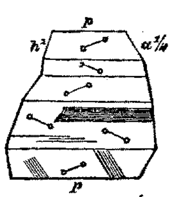
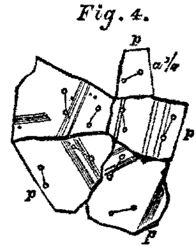


Fig. 4.



White crystals. *Yellow crystal*

bands extinguish the light distinctly, but are penetrated by narrow bandelets which do not extinguish the light, and which make with the base an angle of about 60°, and appear to be parallel to the faces $e^3 = a^{\frac{1}{2}}$. One yellow crystal (fig. 4), very distinctly twinned, as shown by its very decided reentrant angles, consists of five individuals united in the interior along perfectly irregular surfaces. Each of the members of this twin, except the upper small one, contains both bands parallel to p and bandelets parallel to $a^{\frac{1}{2}}$ of the white crystals.

It seems to me that we might retain the name *humite* for the orthorhombic crystals of type I., that of *chondrodite* for the clinorhombic crystals of type II., and seek a name for the crystals of type III.—*clinohumite,* until a better be found. It ought, however, to be ascertained if all the crystals from Sweden and from America belong to type II., or if the brown crystals from Kafveltorp alone belong to this type, while the grey or brownish ones from Ladugrufvan and Pargas are of type III. (Edward Dana admits the last two types in American crystals). It is, however, evident that there is a close crystallographic and chemical relationship between the second and third types, and that they differ most in their optical properties, although Websky tries to show a chemical difference by means of new formulæ, which I declare myself incapable of following. This point will be understood in time; but what was important was to establish first the undoubted facts, and the non-existence of three types of one and the same species, which had always seemed to me an extraordinary thing, difficult to admit, especially in presence of the holohedrism of the one, and the hemihedrism of the two others.