Newsletter No. 255
June 2019

Contents:

To find out more about this photo - read on!

Copy date for the next Newsletter is Thursday 1 August

Robyn Amos, **Honorary Secretary,** ☎ 07595 444215 secretary@bcgs.info	**Andy Harrison,** **Field Secretary,** ☎ 07973 330706 fieldsecretary@bcgs.info	**Julie Schroder,** **Newsletter Editor,** 42 Billesley Lane, Moseley, Birmingham, B13 9QS. ☎ 0121 449 2407 newsletter@bcgs.info
For enquiries about field and geoconservation meetings please contact the Field Secretary. To submit items for the Newsletter please contact the Newsletter Editor. **For all other business and enquiries please contact the Honorary Secretary.** For further information see our website: bcgs.info, Twitter: @BCGeoSoc and Facebook.		

Future Programme

Indoor meetings will be held in the Abbey Room at the Dudley Archives, Tipton Road, Dudley, DY1 4SQ, 7.30 for 8.00 o'clock start unless stated otherwise.

Visitors are welcome to attend BCGS events but there will be a charge of £1.00.

Please let Andy Harrison know in advance if you intend to go to any of the field or geoconservation meetings. If transport is a problem for you or if you intend to drive and are willing to offer lifts, please contact Andy with at least 48 hours notice.

Saturday 15 June *(Field Meeting):* Lydney Cliffs, Gloucestershire, led by John Moseley (Gloucestershire Geoconservation Trust). Meet at 10.30 at Lydney Docks. Good parking at east end of Harbour Road, (GR 647013). Views of River Severn and south to Aust Cliffs, walk along low cliff to access Lydney Cliff section (caution required!), to examine Pridolian sequences. Lunch in Lydney, or at Parkend, 2 miles north of Lydney. Afternoon: Visit to Meezy Hurst (GR 64110896) which displays part of the Westphalian succession and gives an indication of the intra-Carboniferous unconformable contact with the more steeply folded underlying dolomitic limestone at Howbeach Slade (GR 64650905). Finish around 4.00. Bring a packed lunch or there may be an opportunity to buy lunch in Lydney or at the Forest of Dean VC.

Sunday 28 July *(Field Meeting):* Nottingham's Sandstone Caves, led by Tony Waltham. (Engineering geologist and karst specialist). Meet at 10.45 at bollards at the west end of Cliff Road, Nottingham, NG1 1GZ. Nearest car park is Lace Market Car Park, Pilcher Gate, NG1 1QE (about 100 yards to the north). Enter caves at 11.00. The tour will take around one and a half hours. **Please do not be late.** Anyone arriving after 11.00 will not be able to join the cave tour. Numbers limited to 20. Helmets not needed. Torches needed for some parts. The caves are not suitable for wheelchairs or young children. Afterwards we will have a walk through the town to the Tunnel and Castle Rock, with a possible walk via the Church cemetery, time permitting. Aim to finish around 4.00.

Saturday 17 August *(Field Meeting):* An Introduction to Castle Hill. Led by Ian Beech (Wren's Nest Nature Reserve). Meet at 10.00 in the Wren's Nest wardens' office, Fossil View, off Wren's Hill Road, Dudley, DY1 3SB. After tea/coffee, walk from the wardens' base to Castle Hill via Bluebell Wood. We will be visiting managed and unmanaged sites, looking at outcrops and logging areas with any findings. Many of the outcrops are similar to Wrens' Nest so we should be able to make a comparison along with a general introduction to the site.

Friday 13 - Monday 16 September *(Field Meeting):* BCGS trip to Dorset. Led by the Dorset Geological Society. Organised spaces on this visit have now been filled. Any further members wishing to attend will need to make their own arrangements and let the field secretary know.

Monday 16 September *(Indoor Meeting):* 'How and why Earth's land ice cover is changing'. Speaker: Dr Nicholas Barrand (Lecturer in Geosciences, University of Birmingham). The talk will explore the impact of these changes on global sea levels and downstream systems, utilising airborne and satellite remote sensing tools.

Saturday 5 October *(Geoconservation Day):* Details TBC.

Monday 21 October *(Indoor Meeting):* 'A Geological Grand Tour of the Solar System'. Speaker: Andrew Lound. A tour of the solar system taking us on a journey from the sun to the far outreaches of the solar system, along the way visiting planets, moons, asteroids and comets. Illustrated with the very latest images and supplemented by music.

Saturday 2 November *(Geoconservation Day):* Details TBC.

Monday 18 November *(Indoor Meeting):* 'Minerals of the English Midlands'. Speaker: Roy Starkey. This talk explores the rich mineralogical heritage of the area, setting this into a regional, historical and economic context, and tracing the development of mineral exploitation from earliest times to the present day. Mineral specimens from the area are recognised as being significant on a global scale, and are to be found in all major mineral collections, both within the UK and abroad.

Saturday 7 December *(Geoconservation Day):* Details TBC.

Monday 16 December *(Indoor Meeting, 7.00 for 7.30 start):* Members' Evening and Christmas Social. This is our annual chance for members to share their geological experiences in a sociable atmosphere with a Christmas buffet provided by the Society.

Contributions needed from you!

We need a few of you to volunteer to do a short presentation - on any topic with geological connections; or perhaps bring some of your specimens for admiration, discussion and identification. Please contact Keith Elder if you can contribute to this event: meetingsecretary@bcgs.info

Monday 20 January 2020 *(Indoor Meeting):* 'Jurassic Brain Teasers'. Stephan Lautenschlager (Lecturer in Palaeobiology, University of Birmingham). Fossils represent physical evidence for the existence of extinct organisms and have vast potential for the study of ancient life. However, the majority of fossils are preserved in the form of hard-tissues (e.g. bones and teeth), while soft-tissues, such as muscles and internal organs, have withered away. Using modern computer technology and digital visualisation techniques, it is now possible to reconstruct some of these soft-tissues in fossils. The anatomy of the brain is of particular interest, as it can reveal information about extinct animals' behaviours and how they might have sensed the environment around them.

Procedures for Field Meetings

Insurance

The Society provides public liability insurance for field meetings but personal accident cover is the responsibility of the participant. Details can be obtained from the Secretary, and further helpful information can be found in the Code for Geological Field Work published by the GA and available on our website. Schools and other bodies should arrange their own insurance as a matter of course.

Health and Safety

If you are unsure about the risks involved or your ability to participate safely, you should contact the Field Secretary. Please take note of any risk assessments or safety briefing, and make sure that you have any safety equipment specified. The Society does not provide hard hats for use of members or visitors. It is your responsibility to provide your own safety equipment (eg. hard hats, hi-viz jackets, safety boots and goggles/glasses) and to use these when you feel it is necessary or when a site owner makes it a condition of entry. Hammering is not permitted unless specific permission has been sought and granted. Leaders provide their services on a purely voluntary basis and may not be professionally qualified.

Other Societies and Events

BCGS members are normally welcome to attend meetings of other societies, but should always check first with the relevant representative. Summarised information for approximately **two months** is given in our Newsletter. Further information can be found on individual society websites.

North Staffordshire Group of the Geologists' Association

Sunday 14 July at 11.00: Field Trip: Titterstone Clee, Shropshire. Led by Andrew Jenkinson (SGS).

For enquiries: Steve Alcock, Longfields, Park Lane, Cheddleton, Leek, Staffs, ST13 7JS. Tel: 01538 360431 or 07711 501028. Email: steves261@aol.com More info: www.esci.keele.ac.uk/nsgga/

East Midlands Geological Society

Tuesday 25 June at 7.00: Goodluck lead mine, Bonsall. Led by Paul Chandler (PDMHS). £5 donation fee per person.

Non-members are welcome and should register with the secretary. Further info: www.emgs.org.uk or email: secretary@emgs.org.uk

Geological Society, West Midlands Regional Group

Tuesday 11 June: Geoconservation Workshop. Primary speaker: Lesley Dunlop (Northumbria University).

Venue: The Birmingham & Midland Institute, 9 Margaret St, B3 3BS, 6.00 for 6.30. For further details please contact the Group Secretary at: geolsoc_wmrg@live.co.uk Click here for website.

Shropshire Geological Society

Saturday 29 June, all day meeting at 10.00: Church Stretton. Led by Martin Carruthers. Joint meeting with the Shropshire Wildlife Trust.

Booking to reserve a place and obtain joining instructions from Martin Carruthers; email: SGS.Treasurer@hotmail.com; telephone: 01939 233 144. A nominal charge is levied for attendance by non-Members. Further info: www.shropshiregeology.org.uk/

Mid Wales Geology Club

Sunday 9 June: Field trip to Pontneddfachan. Led by Dr Gareth George.

Wednesday 17 July: 'Geology of Lanzarote'. Speaker: Prof Cynthia Burek.

Further information: Tony Thorp tel. 01686 624820 and 622517 tonydolfor@gmail.com
Web: http://midwalesgeology.org.uk Talks at 7.30 at Plas Dolerw, Milford Road, Newtown.

Warwickshire Geological Conservation Group

Saturday 22 June: Bredon Hill. Led by Rob and Boo Vernon, and Deborah Overton. Use will be made of Apps.

Friday 12 July: Malvern Hills. Led by Dick Bryant.

There is a charge of £2.00 for non-members. For more details visit: http://www.wgcg.co.uk/ or email: WarwickshireGCG@gmail.com.

Manchester Geological Association

Thursday 27 June: Brymbo Fossil Forest and Llay Coal Mine tip. Led by Tim Astrop PhD (Brymbo Heritage project) and Jason Parry (Quarry Manager, Hanson Cement Padeswood). Contact: GeoLancashire Secretary.

Contact email: outdoors@mangeolassoc.org.uk For further information about meetings: http://www.mangeolassoc.org.uk/ Visitors are always welcome.

Open University Geological Society

Wednesday 12 June: A weekday trip with a short walk through part of the Birmingham City Centre to view various building stones. Just an afternoon along city pavements with easy slopes. Starting at Victoria Square. Led by Dave Green. Contact Dave Green (davepgreen@btinternet.com).

Sunday 14 July: South Warwickshire Burton Dassett Country Park and Edge Hill Quarry both in the Lower Jurassic. Contact Dave Green (davepgreen@btinternet.com).

Abberley and Malvern Hills Geopark - Geofest

The 2019 Abberley and Malvern Hills Geofest is running from 25 May to 1 September with the usual variety of events and exhibitions. See below for a brief summary of some geologically themed events.

Sunday 9 June and Sunday 14 July, 1.30-3.00: Guided geology and landscape walk at NT Dudmaston. Booking essential, £6 adult, £2 children.

Saturday 22 June 11.35-1.00: Guided Geology Walk at Severn Valley Railway (Highley). Highley Station to the Miners Memorial and back. £2 per person. Meet at station. No booking needed.

Every Wednesday, 24 July to 28 August 10.00-5.00 Celebrating Geology Today - Family Fun Day at Lapworth Museum of Geology, University of Birmingham. Free.

For booking details & the full programme go to: http://geopark.org.uk/pub/2019/05/geofest-2019-2/

Field Meeting Reports

Saturday 6 April: Quaternary of the Severn Valley in Shropshire. Led by David Pannett (Shropshire Geological Society).

Our 2019 field meeting season started by exploring the Quaternary glacial development of the Severn valley, Shropshire between Bicton to the east and Melverley in the west. Conditions were cold and clear when we met David Pannett at Lyth Hill car park at 10.30. The views from Lyth Hill north-west hinted at what the day would reveal.

From Lyth Hill summit we travelled in convoy down to Bicton and David's house for coffee and an introduction to the day's adventure. A retired teacher, David had many helpful handouts and props to illustrate precisely what features we would see and what mechanisms produced them. From Bicton we generally followed the course of the River Severn north-west to Montford Bridge and Shrawardine (and Shrawardine Castle) before ending up at Melverley after lunch.

During the last (Devensian) Ice Age an ice tongue from the North Wales ice cap (the Severn valley glacier) carved a course to Bicton. During its advance and eventual withdrawal, it left numerous sedimentary features behind, hinting at its passing. At Bicton, an elevated roughly north-south curving ridge (or terminal moraine), kettle holes, and variable clay-rich to sand-rich soils define the glacier's eastern most extent around 20,000 years ago before it began to retreat. ►

Exposure at Montford Bridge

At Montford Bridge we saw evidence of the glacier's retreat in the form of sandy glacial till dropped from the glacier as it melted. Meltwater trapped between the retreating ice and the terminal moraine at Bicton flooded the then exposed landscape forming a glacial lake. Into this lake, sediments dropped from the retreating glacier accumulated as 'varved clays', or silt and clay with sand and gravel lenses.

Nesscliffe - Shrawardine moraine

We examined these lake deposits in an exposure at Montford Bridge that was topped with red sands. Red iron oxide from the overlying sands was leaching down into the older varved clays below. At the exposure base were 'drop stones' that had fallen into the lake sediments from melting ice. The red sands originated from later fluvial erosion of the local landscape feeding into the glacial lake where deposition took place.

Heading for Shrawardine we made a couple of brief stops to see a second ridge, curving roughly north-south. Evident from topographic maps, this second ridge that extends from Nesscliffe in the north, to Shrawardine in the south, represented a second moraine (the Shrawardine-Nesscliffe moraine). Easily visible whilst driving along the A5, the ridge hints at a brief pause in the glacier's retreat.

Stopping for lunch at Shrawardine Castle it was very noticeable how the landscape looking west was low-lying and flat. The Breidden and Berwyn Hills rise up in the distance like a gateway into Wales, with the flattened Severn Valley landscape between. David pointed out where the glacial ice would have sat as it retreated. During the glacier's advance, it carved out the local landscape to approximately 50m below sea level. As the glacier retreated, the resulting depression became filled with glacially derived clay rich sediment, and flooded with meltwater to form another vast lake between the retreating ice and the Nesscliffe-Shrawardine moraine. Today this former lake is seen as a relatively flat plain elevated to approximately 60m AOD (Above Ordnance Datum).

Westward view from Shrawardine Castle

We finished at Melverley Church *(see front cover photo)* where David pointed out various interesting features about the local surrounding landscape. Melverley Village sits on a third roughly north-south trending curved ridge – the Melverley moraine, which represents a second brief pause of the retreating glacial ice before it disappeared back into Wales. Following the glacier's departure, rivers such as the Severn and Vyrnwy carved their way through the low-lying post-glacial landscape exposing the sediments deposited within the earlier lakes. Melverley Church is a rare example of a timber church with no solid foundations as there was only glacial sediment and no rock outcrop to build on.

Moraines typically comprise sands and gravels making them relatively harder wearing than the varved lake deposits seen in the lower-lying surrounding landscape. This makes them ideal for locating local villages, in particular Melverley. When the River Severn floods, the local landscape becomes a reminder of the glacial lake that once covered the area as the ice retreated. ►

David showed us Lidar imagery and borehole data that have added to the glacier's advancing and retreating story. Modern flood defence bunds and medieval farming practices are just some examples of landscape features revealed from Lidar imagery; farming having flourished from the nutrient rich soils left behind from times of flooding, and borehole data providing information about the depth of the lake sediments and their nature.

The day finished around 4.00 with a look at the flood plain south-east of Melverley, which provided an interesting lesson on how much we can learn from reading the landscape.

I would like to thank David for his time and look forward to our next outing.

Saturday 11 May: Visit to Martley Village, led by John Nicklin (Teme Valley Geological Society).

BCGS members met Teme Valley Geological Society (TVGS) members John Nicklin and Ian Pennell at Martley Village Memorial Hall, a centre for many local village events. Over tea and biscuits, John gave a bit of background about the Society, the local geology and suggested where we should go. Throughout the day the weather was warm and sunny.

Penny Hill Quarry Limestone

Since 2011, TVGS accompanied and encouraged by local community support and through European funding, have produced initiatives aimed at making local geology more accessible to the public.

Martley is located on the eastern edge of the Teme Valley, Worcestershire, approximately 11km north-west of Worcester City Centre and 7km south of the village of Abberley. The River Teme rises in the Kerry Hills, Powys and flows 80km in a roughly north-west south-east direction, before joining the River Severn south of Worcester. The longest tributary of the River Severn, the River Teme lies 900m west of Martley.

The local landscape is relatively low-lying and undulating with isolated ridges, masking a varied geological sequence and complex deformational history. To the north and north-west are the green tree-covered slopes of Penny Hill, Woodbury Hill and Abberley Hill. To the south-west lies Berrow Hill. In the far distance are views towards the Black Country and Clent Hills (north-east), the Severn Valley (east), the Malverns (south), the Cotswolds and Bredon Hill (south-east), the Teme Valley and Bromyard Plateau (west) and Clee Hills (north-west).

Scar Cottage Quarry

The solid geology underlying Martley and seen within the surrounding landscape covers some 470 million years of geological time, from the Precambrian Malverns Complex (700 million years old) to the Jurassic Oolitic limestones of the Cotswolds and Bredon Hill. ►

Our first stop was Penny Hill (Penny Hill Quarry, The Canyon and the Stairway to heaven) to look at Silurian Wenlock limestone rocks identical to the Nodular Member seen at Wren's Nest. The rocks here comprise tilted thinly bedded fossiliferous limestone and shales, with corals, brachiopods and bentonite layers. The exposures present were left behind after purer limestone layers were quarried for use in agriculture and as building stone. Most of the resultant quarry was later landfilled to raise the hill profile back to what it once was.

Next, we stopped at Scar Cottage Quarry, situated within the privately-owned back garden of a TVGS member. However, it is only open for organised group visits. The quarry comprises exposures of red-brown, cross-bedded, channelised Triassic Bromsgrove Sandstone. The beds show evidence of fracturing, faulting and carbonate mineralisation from capillary water migrating through fractures in the rock. Historically, the sandstone was worked for building stone. However, weathered voids and collapsed blocks are testament to the rock's poor quality.

Martley Rocks Investigation Trench

After lunch we walked across adjacent fields admiring the local views before ending up at our last stop for the day - Martley Rocks. Located within a farmer's field, this site comprises a fenced-off long trench excavated during investigation works to expose a rock sequence representing 700 million years of underlying geological history. The trench is all that remains of a larger trenching investigation that enabled the TVGS to map out the underlying strata and establish the location of the Martley Rock and East Malvern Faults. The rocks exposed include Malverns Complex (Precambrian), Malvern Quartzite (Cambrian), Raglan Mudstone (Silurian / Devonian), Halesowen Formation (Upper Carboniferous sandstone) and Bromsgrove Sandstone (Triassic). All this tells a story centred around mountain building, thrusting, rifting and environmental / geographical change from coastal shallow marine conditions south of the equator, to arid desert and fluvial floodplains at more equatorial latitudes.

Apart from being a very attractive area to visit, Martley and the Teme Valley has much interesting geology to explore. I would like to thank John and Ian for their time and look forward to teaming up for more events in the future. ■

Andy Harrison

Friends of Saltwells Nature Reserve

As a new member of both the BCGS and Friends of Saltwells Local Nature Reserve, I am enthusiastic about establishing connections between the two communities and hopefully this will contribute to a better understanding of its geology at a personal level. ►

Therefore, I will start by introducing myself and briefly explaining my background, motivations and aspirations. As evidenced by my surname, I come from Spain, although I studied geology in three different universities: the University of Barcelona, the University of Iceland as an exchange student, and the University of Oviedo, the latter being where I graduated. During my undergraduate degree in geology I worked as a scholar for two years in the Cartographical and Geological Institute of Catalonia, within the Geotechnical and Drilling Department. Once I graduated, I worked for an environmental company in Belgium for 6 months.

The Inclined Tramway before...

However, none of the previous working experiences seemed to fulfil my expectations, and this is the reason why I decided to study for a postgraduate degree. After being accepted to study a fully funded master's degree in the University of Vienna, I declined the offer in favour of the MSc degree in Applied & Petroleum Micropalaeontology in the University of Birmingham, which I found intellectually stimulating and, at the same time, an opportunity to improve my job prospects. However, the isolating nature of that discipline was demotivating, especially for someone who enjoys teamwork and engaging with the general public.

The link between myself and Saltwells had nothing to do with my postgraduate degree. Instead, I discovered this site when I was gathering information to create a report on the closure of quarries in the UK, as a part of a project within an environmental management professional course I did back home. I read that volunteers could occasionally be used for geoconservation tasks and I decided that I could become one of them. As a matter of fact, I contacted TCV (The Conservation Volunteers) and they offered me the opportunity to volunteer in the Doulton's Claypit in Saltwells Local Nature Reserve on a regular basis. In turn, a further knowledge on the geology of the site and of the Black Country as a whole is what has brought me to join this Society.

Since its inaugural meeting on 21/03/2019 the Friends of Saltwells Nature Reserve has gained formal status which enables the community to apply for resources. This group originates from the 'Save Our Saltwells Nature Reserve' campaign group set up in October 2018 to oppose a planning application for 9 houses to be built in the middle of the woodland. In December 2018 the planning application was refused, resulting in a clear example of community success. However, once a planning application is refused, there is a period of 6 months to appeal, which establishes the deadline on the 06/05/2019.

...and after geoconservation

Regardless of the outcome, there are two other main objectives that have been clearly identified. Firstly, what is essential for this group is to build facilities for both the staff and volunteers working on the nature reserve, as well as for the visitors. Secondly, they hope to achieve a National Nature Reserve status by summer 2019 and, by doing that, Dudley would become the only Council within the UK to possess two National Nature Reserves. ►

Geoconservation tasks are a weekly routine in Saltwells, where its landscapes have gone through a transformation during the last months. After all the hard work performed within the Doulton Claypit, the work has currently moved towards a clearance of the rock faces along the tramline connecting the quarry with the canal. Every Thursday, the wardens alongside the volunteers perform different conservation tasks targeting the geology. In addition, TCV undertake tasks on Tuesdays with increasing numbers of volunteers due to partnerships with Merry Hill Shopping Centre, NatWest or RBS. These partnerships constitute a win win situation, since the participants get a day out of the office, or their usual workplace, and TCV receives volunteers.

Contractors developing a path

I know that BCGS is already involved in geoconservation work in the Reserve, but if you live near Saltwells or want to do more volunteer work, I would highly recommend signing up to this group since it will constitute a key role within the Black Country Geopark.

My role as a TCV volunteer officer is to assist the project officer during the preparation, performance and closure of each Environmental Action Day (EAD). However, when possible and before starting the actual work, I also do the 'geology talk' or 'motivation talk' in which I give a brief overview of the geology as well as highlighting the importance of the tasks. In my opinion, it is important to explain that clearing the rock faces is not just important for geologists or scientists, but also to improve the accessibility and visibility for visitors and neighbours to enjoy. Believe it or not, this introduction boosts their motivation to work and this is reflected in the outcomes.

Apart from the regular geoconservation members (wardens, TCV staff and volunteers) some contractors might be hired occasionally to develop paths within the reserve. I helped the senior warden supervise the contractors on 02/04/2019.

Within the volunteer groups, I would highlight the work done by Saltwells Clean & Green, focussed on litter picking. This activity is of enormous importance because it releases the wardens backlog and enables the latter to focus on the work they are qualified to do. On 24/03/2019 the work was focussed around the Netherton Reservoir entrance to the Reserve, which doesn't belong to Dudley Council and, therefore the wardens are not allowed to clear it.

Saltwells Clean & Green litter picking group

Last but not least, I intend to create a Geological Handbook and Field Guide for Saltwells, similar to the one for the Wren's Nest, which includes a cross section, stratigraphical divisions, sketches of both landscapes and fossils of the different geopoints, as well as a glossary and references. ■

Arnau Tort García

For more information about Saltwells Nature Reserve or the Conservation Volunteers, please contact:

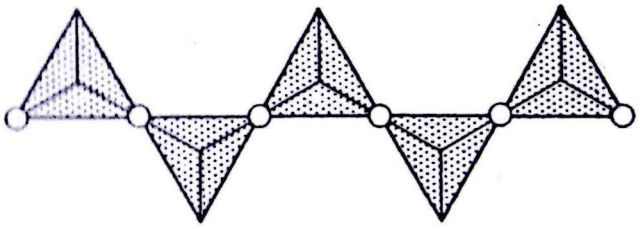
Alan Preece, Senior Warden, Saltwells LNR: 07920 235036, email: Alan.Preece@dudley.gov.uk

Glenn Powell, Project Officer, The Conservation Volunteers: 07584 402549, email: g.powell@tcv.org.uk

Mike's Musings No. 21
Silicates: the Overlooked Minerals? Part 2

Continuing with the theme of silicate structures, we finished Part 1 with one way in which mineral structures have **two shared oxygen atoms** between adjacent tetrahedral units**.** There are two further ways in which this can be achieved. These are by arranging the tetrahedra not in rings (as before) but in chains. This leads us to the **'chain-silicates'** (Deer, Howie and Zussman) or **'inosilicates'** (inos = a fibre or a thread, as Holmes calls them), which give us two important families of 'rock-formers'.

Fig.5 Inosilicates: Si_2O_6 = Si_4O_{12}
single chain of tetrahedra
each sharing 2 oxygen atoms

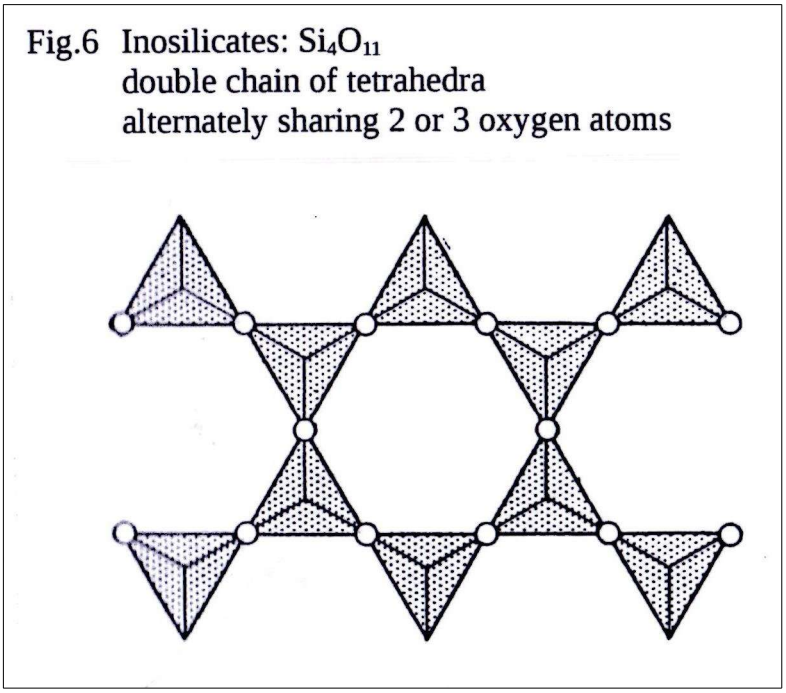


Firstly come the *pyroxenes* in which the structure is based on **single chains** of conjoined tetrahedra in which each silicon atom is again always linked to 3 oxygen atoms (base unit of SiO_3 or Si_4O_{12}) (**Fig.5**). There are many members in the *pyroxene* family of which *augite* is perhaps the most familiar.

Secondly, as we have seen before, there are often 'hybrid structures' that 'mix and match' properties. This happens once again with the **double chain** *amphibole* family of minerals in which, by virtue of two chains lining up alongside each other, **two OR three oxygen atoms are alternately shared (Fig.6)**. This reduces the base unit still further from SiO_3 to $SiO_{2.75}$ (or Si_4O_{12} to Si_4O_{11}). Again, there are many *amphibole* minerals, of which *hornblende* is probably the best known.

It is ironic that the most familiar (and certainly more common) of the pyroxenes and amphiboles are amongst the most chemically complex within each family.

Fig.6 Inosilicates: Si_4O_{11}
double chain of tetrahedra
alternately sharing 2 or 3 oxygen atoms



Logically the next step in the structural progression is that in which the adjacent tetrahedra **all share three oxygen atoms** with each other, and this is exactly what we find in the so-called **'phyllosilicates'** (phyllon = a leaf), in Holmes' nomenclature. This bit of Greek is also reflected in Deer, Howie and Zussman's more common group name, the **'sheet-silicates'**, which include the familiar *mica* family, *talc* and *serpentine*, as well as the very important family of *clay minerals*. In sharing 3 oxygen atoms all round, the base unit is reduced still further from $SiO_{2.75}$ to $SiO_{2.5}$ (or Si_4O_{11} to Si_4O_{10}) (**Fig.7**). ►

In many of the minerals discussed so far, some of the silicon atoms are usually replaced by aluminium atoms. This is particularly the case amongst these **'sheet-silicates'**, and this factor has knock-on effects for the nature of the remainder of the chemical composition, in order to maintain a balance between the positively and negatively charged constituents. However, it does not affect the validity of the structural differences between the various groups.

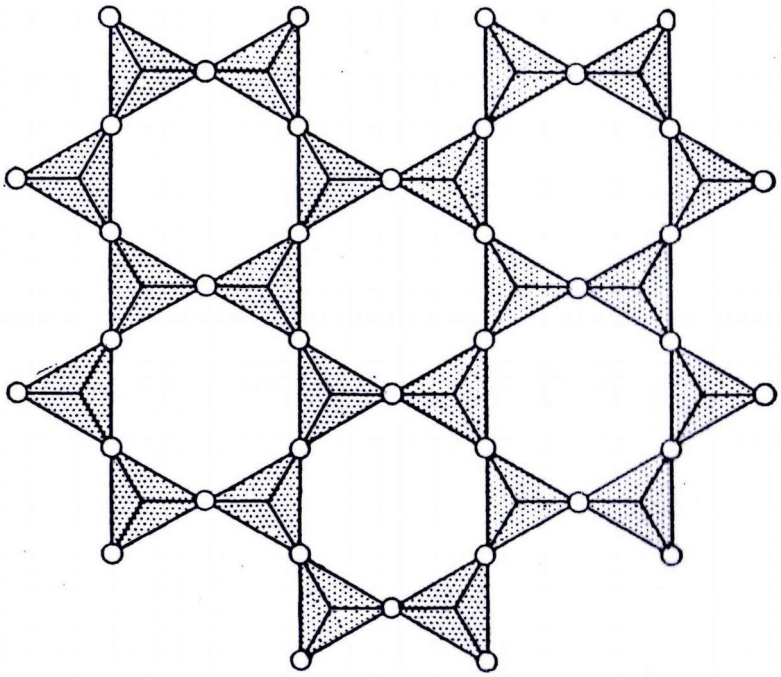


Fig.7 Phyllosilicates: Si_4O_{10} sheet of tetrahedral each sharing 3 oxygen atoms

The final group left to recognise are those minerals in which **all four oxygen atoms** of the basic tetrahedron are shared. This can only be achieved by means of a three-dimensional **'framework'** structure, in which oxygen atom-sharing occurs in a 3-D array (all previous structures can be accommodated in two dimensions), with the third dimension completed by other chemical constituents in the mineral's make-up. This group is also known as the **'tectosilicates'** (tecton = a builder). Once again, the base unit is reduced such that the Si:O ratio falls to its minimum of 2:1. The result is that we arrive at SiO_2 (or Si_4O_8) which includes *quartz*. Once we begin replacing silicon with aluminium we can include several other mineral families within this group, notably the very important *feldspars*, as well as the closely related *feldspathoids* and the utilitarian *zeolites*.

At this stage it may help to summarise all this information in simpler, tabular form.

The 'Rock Formers' - **Structural types**

(Deer, Howie & Zussman nomenclature)	(Holmes nomenclature)	Si:O ratio	No. of shared Oxygen atoms	*Mineral Examples*
Orthosilicates	Nesosilicates	4:16	0	*Olivine, Garnet*
	(hybrids) ?	4:15	0/1	*Epidote*
Di-silicates	Sorosilicates	4:14	1	*Melilite*
Ring-Silicates	Cyclosilicates	4:12	2	*Beryl, Tourmaline*
Single-Chain Silicates	Inosilicates	4:12	2	*Pyroxenes*
Double-Chain Silicates	Inosilicates	4:11	2/3	*Amphiboles*
Sheet Silicates	Phyllosilicates	4:10	3	*Micas, Clays*
Framework Silicates	Tectosilicates	4:8	4	*Quartz, Feldspars*

►

If you have put up with things thus far, you are entitled to ask 'so what'? Well, to my mind this illustrates how mathematically straightforward and beautiful Mother Nature can be at times. Einstein sought elegance in Nature when wrestling with the mathematics of the quantum world, and hated things that didn't boil down to simplicity itself. Of course, ultimately he failed in his efforts to describe the whole of Nature in simple terms (the 'Theory of Everything'), but people are still trying to do so - and who knows, perhaps everything might one day be condensed into just one single, simple equation.

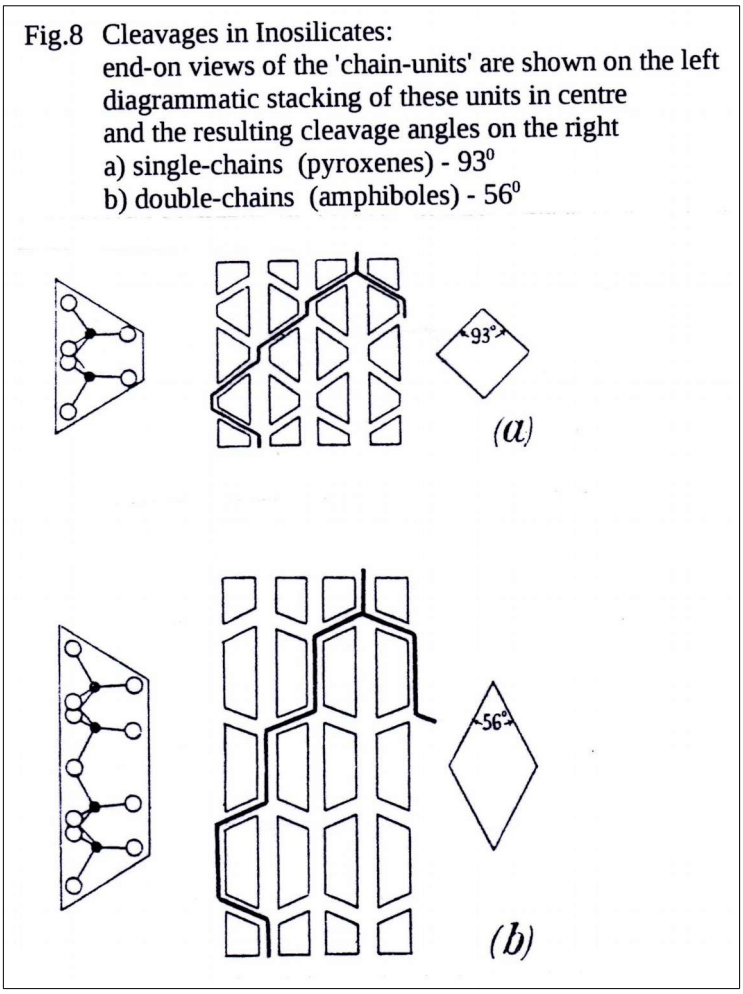


Fig.8 Cleavages in Inosilicates:
end-on views of the 'chain-units' are shown on the left
diagrammatic stacking of these units in centre
and the resulting cleavage angles on the right
a) single-chains (pyroxenes) - 93^0
b) double-chains (amphiboles) - 56^0

At a more practical level it is possible to understand several general trends in the physical properties of the main families of **'rock-formers'** (olivine – pyroxenes – amphiboles – micas – feldspars – quartz) in terms of their atomic structure. Their ***density***, for instance, decreases as the atomic structure becomes more tightly controlled by oxygen-atom sharing: from around 3.4 in olivine and pyroxene to around 2.6 in quartz and feldspar. Similarly the optical property of ***refractive index*** diminishes from around 1.7 in pyroxene to around 1.5 in feldspar. Olivine is only 1.65, so trends don't always work throughout, as other factors come into play.

In another general way, these structures influence the ***melting points*** of these minerals. The 'more free' structures crystallise first, with the more 'shared' structures developing last. This is seen most effectively in the typical order in which they crystallise from a cooling magma. Bowen recognised this in establishing his **'Reaction Series'** which begins with olivine and calcium-rich plagioclase feldspars forming early, followed progressively by pyroxene, amphibole and biotite-mica, alongside increasingly sodium-rich plagioclases, ending with orthoclase feldspars, muscovite-mica and quartz. (This, you may notice, also dictates a progressive differentiation of the parent magma, from ultrabasic to acid).

Hardness and **cleavage** show a more specified relationship to atomic structure that goes beyond the simple 'silicate-structure'. Most of the minerals mentioned have relatively high values on Moh's hardness scale: basically silicate minerals are hard by virtue of their silicon content, but where there are specific planes of weakness within the overall structure, this is much reduced (as in micas and clays with their sheet-like structure, and to a lesser extent in pyroxenes and amphiboles with their chains). Cleavage is similarly influenced, and there is a nice correlation between the contrasting angle between pairs of cleavages in pyroxenes and amphiboles and their respective 'chain-thicknesses' when viewed end-on (**Fig.8**), which provides a convenient point on which to finish. ■

Mike Allen

Reference: Figures 5-8 from 'The Principles of Geology' by Arthur Holmes, 1944.