Farnham Geological Society

(A Local Group within the Geologists' Association)

NEWSLETTER SUMMER 1997

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For this Spring number (Spring is late this year!) we have to thank four members and at last we have some reports of our memorable field trip to the USA of 1996.

First there is there is the last instalment of Roger Ashcroft's report on our Shropshire Field Trip of August 1995. This is followed by Cath Clemesha's account of our visit to Yellowstone National Park.. Next we have the report by David Stephens on Places of Engineering Interest on the USA trip. Finally we have an article by Cyril Dutton on Fun Finding Erratics. This will appeal to those who, like your Editor, always enjoy beachcombing.

Further reports on the USA this will occur in the next one or possibly two Newsletters.

Shropshire 25, Some Thoughts from the Milton Keynes Outlier

This is a continuation of Roger Ashcroft's article from the last Newsletter.

Day 5 Ordovician Intrusive Rocks

This was a day in the hills looking at the scenery and the intrusive and volcanic rocks of west Shropshire. Part of the visit was to see the effects of these rocks on the surrounding country rock with sometimes quite unusual results.

Corndon Hill To the west of the Stiperstones, visited on day 2, the Ordovician rocks were folded in late Ordovician times into a structure comprising two major north/south folds-the Ritton Castle Syncline and the Shelf Anticline. Into the Hope Shales, now seen in the anticlinal core, was intruded a mass of dolerite, forming the prominent Corndon Hill. Intrusion took place into the pre-existing arch of the Shelve Anticline forming a lens shaped mass of phacolith.

The first exposure visited was a small quarry on the west side of the hill. Contact metamorphism had transformed the shales to a spotted slate. Andalusite crystals, occurring in low grade thermally metamorphosed rocks, had broken down to chlorite, giving the crystals an orange colour.
Towards the top of the hill the dolerite was seen in outcrop, much frost shattered during glaciation. Greatly altered and with large crystals, the exposure was criss-crossed by apatite veins, the last fraction to crystallise out during intrusion.
The Corndon Hill dolerite, coupled with andesite and picrite also exposed in the vicinity, constituted a large intrusive mass and was a considerable source of heat for the volcanic rocks seen in the surrounding area.
The view from the hilltop, as on so many Shropshire hills, was outstanding.
Barytes, formed in hydrothermal veins, was mined on the western flank of the hill.
The Breidden Hills North of Corndon Hill and separated from it by the syncline of the Long Mountain, composed of Silurian rocks, are the Breidden Hills.. They are Ordovician rocks similar to those of the Shelve area and contain dolerite and andesite intrusions.
Two unusual exposures were visited on Middletown Hill, south of Breidden Hill. The first was a coarse conglomerate containing large, rounded andesite clasts set in a coarse, gritty matrix - a weathered volcanic ash. Described as "bombs" in the regional guide, an alternative explanation is that the conglomerate, with rounded pebbles, was a high energy beach deposit accumulating around a volcanic cone. Erosion of andesite, a high level deposit in a volcanic cone, along with volcanic ash and subsequent deposition has formed the conglomerate. The rock is unusual due to the large size of the deposit which forms several hills in the immediate vicinity.
In an excavated gully nearby, the second unusual exposure was a fault breccia associated with a volcanic vent. The solidified andesite in the vent had been fractured into angular fragments by a second eruption. These had then been incorporated into a matrix of volcanic ash to form the breccia.
A third exposure was visited at New Pieces Ridge on the southern flank of Breidden Hill. This was composed of basaltic pillow lavas incorporating shale sediment. The vesicles in the lava, originally gas-filled, are now infilled with calcite.

The Riddle of the Square Quarry The fourth 'evening surprise' was Grinshill Hill, a high standing faulted block in the New Red Sandstone, forming an outstanding viewpoint seven miles north of Shrewsbury. It is similar to Nestcliffe, seen on Sunday evening. Composed of buff coloured sandstone that has been baked by the Grinshill dolerite dyke, it is a valued, much quarried building stone.
There are many disused quarries in the immediate area, all with the vertical faces and right angled corners so characteristic of the Nestcliffe Quarries. One in particular is unusual. It is small, deep, vertical sided, square in plan view with four vertical sides and no obvious means of access. How was it worked?

Day 6 Recent Glaciation
The final day was another trip to the hills, looking at the fine Welsh scenery and the effects of recent glaciation on the landscape.
Berwyn Mountains To the north west of the Breidden Hills, in North Wales proper, a thick sequence of Ordovician sediments and volcanics, folded into an east to west trending anticline, form the Berwyn Hills. The sequence contains a number of acid

intrusions. The area is part of the deeper-water basin area of Wales. Sedimentation continued until the end of the Ordovician and into the Silurian. The folding was late Silurian in age.

Pistyll Rhaeadr The delightful waterfall of Pistyll Rhaeadr, 72 metres high, lies at the head of the valley of the Afon Rhaeadr in the southern Berwyn Mountains. There was also a tea shop, but more of that later.

Vertically bedded microgranite lying over slates are the rocks over which the waterfall plunges. In the plunge pool the slate shows both cleavage and bedding, which is unusual as one or the other usually predominates. It is rare to find both equally developed. Cleavage occurs perpendicular to pressure applied during metamorphism, causing recrystalisation along the cleavage planes.

Regional metamorphism had occurred due to the presence of microgranite igneous intrusions in the immediate area.

Nant - y - Llyn Valley To walk up this valley was to walk up a classical glacial, U - shaped valley. The microgranite sill was exposed high up in the valley sides. Above the steep wall at the end of the valley were two hanging valleys, formerly occupied by tributary valley glaciers which, because of their small size, failed to deepen their valleys at the same rate as the main glacier deepened the main valley.

After a steep climb up the end wall of the valley, a stop was made at an exposure of the microgranite sill. The microgranite was well jointed with quartz veins. The contact area with the country rock was baked into a hard hornfels which graded into a spotted slate, similar to that seen earlier in the week on Corndon Hill.

Above the main valley, both hanging valleys were visited. The first was dry, containing no corrie lake. The uneven surface showed ample evidence of solifluxion, the downward movement of soil under the influence of gravity as a result of the alternate freezing and thawing of the contained water.

The second hanging valley contained a glacial lake, Llyn Lluncaws, which occupied about 20% of the sheltered east facing corrie. The location was a pleasant spot to rest awhile. It would have been even more pleasant but for the rain. Yes, it did rain in August 1995!

The ridge between the two valleys was formed into a stepped arete, the steps being formed by occasional movements of ice over the ridge at different levels.

The last location visited on this last active day of the anniversary field trip was the tea shop, a fitting , civilised end to the outdoor activities. However we were not finished yet, more was to follow. We were to have an evening session where the whole of the week's activities were reviewed and put into context.

Review Session Pre-Cambrian to Extremely Recent

Pre-Cambrian

The Iapetus Ocean was well established with Shropshire lying on the margin, sometimes onshore, sometimes offshore. The Uriconian volcanics represented continental vulcanicity on the continental side of a subduction zone lying offshore. The late Pre-Cambrian lavas, tuffs and breccias were mostly laid down in water.

The Church Sretton Fault system and the parallel Pontesford-Linley Fault system were established at this time, both running parallel to the subduction zone.

Subduction between these two faults led to the formation of a shallow marine trough in which the Longmyndian was deposited. The eastern Longmyndian, with contemporary

Uriconian vulcanicity, was deposited first, uplifted and eroded before the deposition of the western Longmyndian.
Extreme folding occurred at the end of the Pre-Cambrian.

Cambrian

The Iapetus Ocean was widening, conditions were stable, there was no offshore subduction zone and volcanic activity was absent. Deposition was in shallow water. There were minor earth movements, probably associated with the Church Stretton Fault, which gave rise to breaks in deposition. The Upper Cambrian is missing.
The Iapetus Ocean began to close in late Cambrian.

Ordovician

The oceanic area narrowed throughout the Ordovician. A subduction zone was active offshore. Shallow water deposition was followed by deeper water. There was a facies change between the east and west of the Church Stretton Fault system. Massive volcanic activity occurred together with major intrusions. Both were associated with the late Taconian orogeny which gave rise to folding at the end of the Ordovician and resulted in mineralisation.

Silurian

The sea retreated with a break in deposition. Later in the early Silurian, the sea again transgressed to form shallow water deposits. Shallow water shelf facies were deposited to the east of the Church Stretton Fault system. To the west, the sediments changed to a deeper water basin facies.
Volcanic activity was at an end in Shropshire but some was occurring further afield. The Iapetus Ocean finally closed at the end of the period with gradual uplift to form a continental mass. The Ludlow Bone Bed marks the transition from marine to non-marine deposition.
The Caledonian Orogeny of the late Silurian in Wales had a minor effect in Shropshire.

Devonian

Dry, arid conditions existed with large rivers crossing the deserts. It was a fairly stable environment with deposition of cross bedded sandstones, fossil soils and pebble beds associated with river channels. Late Caledonian orogenic activity formed the Titterstone Clee syncline and the Ludlow anticline.

Carboniferous

A return to marine conditions took place, passing to non-marine by the end, as the Hercynian earth movements brought the period to a close. Throughout the period, crustal instability determined the sedimentation, giving rise to coal measures, limestones and some sandstones.
Igneous activity occurred with dolerite intrusions.

Permo-Triassic

Deposition was of bright red, dune bedded sandstones together with river and lake sediments. Desert conditions occurred with mountain areas to the south. The rivers flowed north: the opposite conditions to those that existed during the Devonian.

Recent
Massive glaciation approached from the Welsh mountains to the west and north. The high ground in the west of the area deflected the advancing ice so that the east did not experience glaciation.

Extremely Recent
Metamorphic outlier, highly coloured, soft in texture with a chilled margin. There was evidence of recent thermal activity. We were fortunate to be able to study this in hand specimens and very interesting it was. Those readers who were there will probably have guessed what is being referred to. It was the anniversary cake with the appropriate number of 'hot spots', the 25 candles.
The faulting of this uplifted block was ably implemented by the long standing treasurer, Peter Luckham.

Epilogue
The celebration described above was a fitting end to what had been a most interesting and enjoyable field trip. There was an immense satisfaction in starting the week in the Pre-Cambrian and logically working up the stratigraphical column to Recent Glaciation on the final day. Uriconian to Post Glaciation in six days, at up to 120 million years a day, is really high speed geology.
The structure of the course, the location, the viewpoints, the 'evening surprises', the briefing and debriefing sessions and the facilities at the field centre all combined to make the 25 year anniversary field trip a most memorable occasion.
For this I must thank David Cronshaw for all the effort put into the organising and running of the course. I must also add special praise for his fortitude under the withering hail of 'heavy duty' questioning, not least from myself.
Those readers who have 'stayed the course' will remember my speculation on the journey to Preston Montford. At the end of the week my initial impressions were not contradicted. The field centre and the staff had provided a very comfortable and enjoyable stay.
To Peter Luckham, and any others involved, go my thanks for the organisation of the field trip and for the invitation to take part.
My first ever geology field trip was on the 14 February 1971 to the Coxbridge Sandpit near Farnham where about 2.5 metres of Gault clay and river gravels overlie leached Folkestone Sands. Yes, I took copious notes in those days as well! Having returned to active field geology after quite a long absence, I had quite forgotten how enjoyable the subject can be when you are with a group of like minded people. From this the flame has been rekindled. The message from the Milton Keynes Outlier is therefore that I hope to meet up with members of the Farnham Geological Society in some distant field location in the not too distant future. South Wales perhaps?

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YELLOWSTONE NATIONAL PARK

Yellowstone National Park is mainly in Wyoming, with Montana and Idaho to the north and west. It is a vast rhyolitic volcanic area with major eruptions at 2 Ma, 1.2 Ma and 600,000 years ago; the last resulted in the central portion collapsing leaving a massive caldera 28 by 47 miles. It is an area of numerous geysers, hot springs, fumaroles and mud pots, so it is still very active. There are spectacular waterfalls many of which are at or near the wall of the caldera. Elevation in mainly between 7000 and 8000 feet.

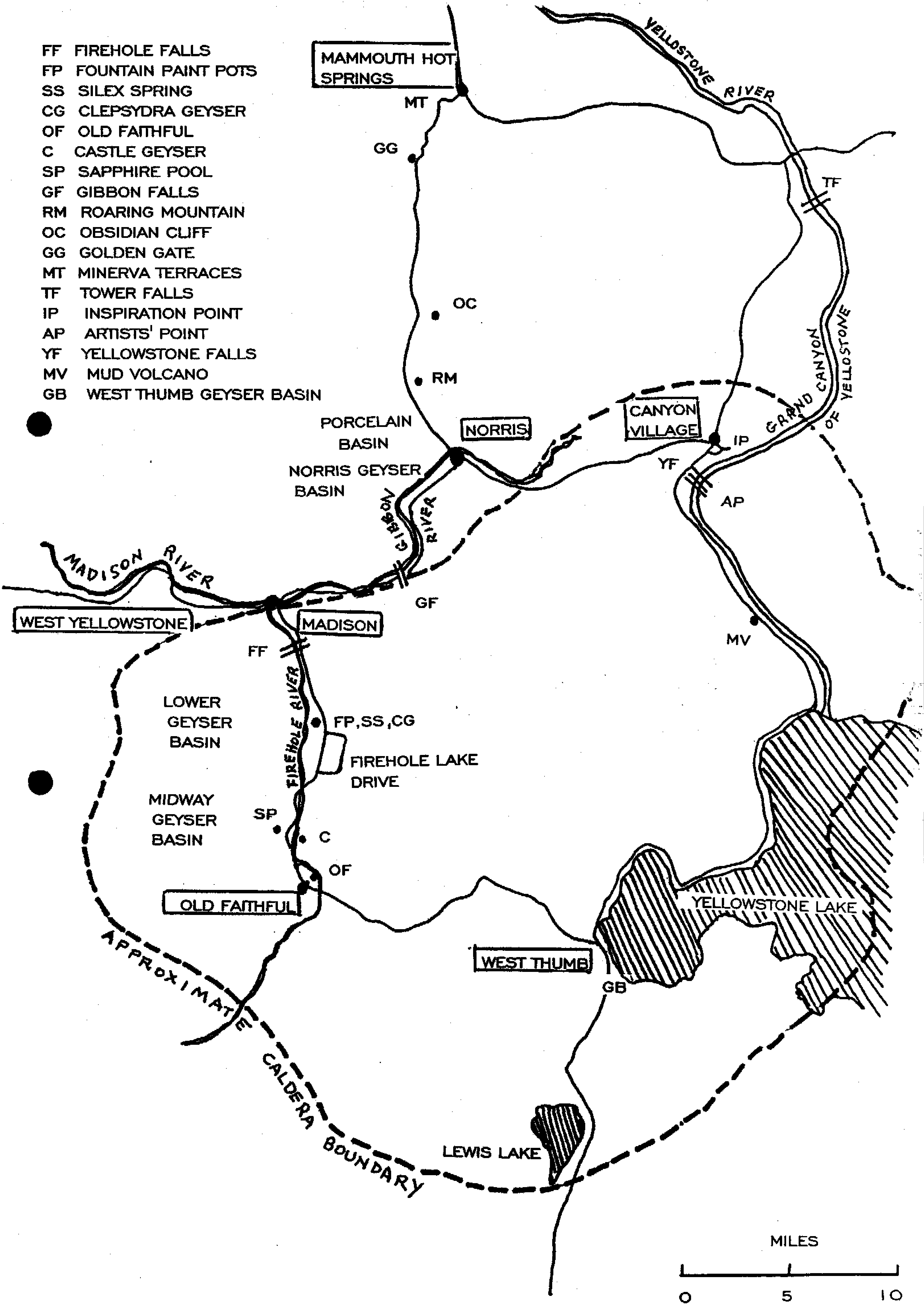
From **West Yellowstone** at 6667 feet we climbed eastward up to the rim of the caldera at **Madison** 6806 feet through a forest where we saw elk, moose and bison. At Madison we turned south towards **Old Faithful** passing first the vertical wall of the caldera and then through flat open country along the **Firehole** river. We got some good photos of grazing bison here. Our first stop to view hydrothermal effects was at **Fountain Paint Pots** in the **Lower Geyser Basin.** Steam and the bright colours in the pools were most obvious.

At Old Faithful we signed in at **Snow Lodge** then went to benches conveniently placed near **Old Faithful Geyser** and waited. Cameras were at the ready - not as tedious as it sounds because Old Faithful erupts about every 75 minutes and last for 1½ to 5 minutes - so one checks at the Lodge when the next eruption is expected. The one we saw was not, according to experts nearby, particularly spectacular. Looking across the landscape you see a lot of patches of steam rising from mainly white rocks with streaks of yellow, red and brown. Even the Firehole river behind Old Faithful seemed to be steaming.

Next morning we retraced our steps to Madison then continued north towards **Mammouth Hot Springs** passing several geyser basins and the **Gibbon Falls** at the edge of the caldera, stopping to explore the **Porcelain Basin.** It is a deep flat basin that you walk down into and across board-walks passing different coloured steaming hot springs. It is the Park's hottest exposed area. Then there was **Roaring Mountain,** a clayey landslide. Our next stop was **Obsidian Cliff** where we saw fresh and partly devitrified obsidian with some having flow banding. It was one of the few places we could actually TOUCH ROCKS! Further on at **Golden Gate** there is pinkish rhyolite on the left and a steep drop on the right with trees fossilised in situ by volcanic ash. After that we were in mid-Carboniferous much cracked Madison Limestone until we reached Mammoth Hot Springs.

This is a magnificent collection of terraces mainly white with the usual colours made of travertine rather than silica sinter. The calcium carbonate -rich liquid has flowed over ridges and drops like a series of curtains into flat pools with shallow rims which the liquid then overflows down into another series of flat pools to the bottom of the hill. The most spectacular are the **Minerva Terraces.** There were two elk standing conviently at the top just waiting to be photographed.

After lunch we drove east then south to **Canyon Village** where we spent the night. This is very near the 1000 foot deep **Grand Canyon of the Yellowstone** and the **Upper and Lower Falls** on the Yellowstone river. We saw the Grand Canyon from **Inspiration Point** then crossed the river a little farther south towards **Artist's Point** to view Lower Falls and then another viewpoint to see Upper Falls. The path we should have walked down for a much better view was closed.


FF FIREHOLE FALLS
FP FOUNTAIN PAINT POTS
SS SILEX SPRING
CG CLEPSYDRA GEYSER
OF OLD FAITHFUL
C CASTLE GEYSER
SP SAPPHIRE POOL
GF GIBBON FALLS
RM ROARING MOUNTAIN
OC OBSIDIAN CLIFF
GG GOLDEN GATE
MT MINERVA TERRACES
TF TOWER FALLS
IP INSPIRATION POINT
AP ARTISTS' POINT
YF YELLOWSTONE FALLS
MV MUD VOLCANO
GB WEST THUMB GEYSER BASIN
MAMMOUTH HOT SPRINGS
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PORCELAIN BASIN
NORRIS
CANYON VILLAGE
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NORRIS GEYSER BASIN
GIBBON RIVER
MADISON RIVER
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WEST YELLOWSTONE
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FIREHOLE RIVER
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The following day we continued south, back into the caldera , along the **Hayden Valley** with the wide smooth winding Yellowstone river until it flowed into **Yellowstone Lake.** At one time the lake extended much further north and the river now flows through the former lake bed. The sediments produced soil suitable for shrub land but few trees. Wildlife to look out for included elk, bison and moose. The lake is the largest mountain lake in North America at 20 miles long, 14 miles wide and 320 feet at its deepest. It is considered to be a recent caldera and has thermal activity along its edges. We stopped in the Hayden Valley for a quick look at **Mud Volcano** and **Dragon's Mouth Spring** before having our last look at hydrothermal activity at **West Thumb Geyser Basin** on the lake shore. Here the heat source is considered to be quite close under the surface and if the lake level fell a few feet there could be a catastrophic steam explosion.

We had got quite used to walking through a damp, slightly sweet smelling steam with hydrogen sulphide. It was always hot and sunny and the air quite rarefied because of the altitude.

There has been a lot of devastation of the forests by fire; and the acid fumes cannot do them much good either. Consequently there are vast areas were covered with dead tree trunks and stumps which gave the place a desolate look. This does not however detract from the enjoyment of the thermal displays.

<u>A few notes in explanation</u>

<u>Geysers</u>: Lots of rain and snow seep down fissures and cracks in the rock until it reaches the hot rocks heated by magma beneath. Hot water rises dissolving silica on its way up. At the surface silica may be deposited blocking up the vent. Pressure will build up until there is sufficient to blow a hole in the sinter, reducing the pressure to produce a massive volume of steam.

<u>Hot Springs</u>: As for geysers except that the vent does not get blocked.

<u>Mud Pots</u>: Water supply here is limited. It is made acid by dissolved hydrogen sulphide and sulphur being converted into sulphuric acid by bacteria. This dissolves surface soils and converts feldspars into kaolinite which mixes with silica to form mud. Bubbling is aided by the escape of hydrogen sulphide, carbon dioxide and steam.

<u>Colours</u>: Yellow is caused by bacteria living in water at 167°F . As it cools the colour goes darker through orange, brown and green. Different bacteria and algae will modify the colours at 113°F to 131°F. Yellow or pink strands at 196°F (at this altitude the boiling point of water is 199°F) are caused by sulphur, iron oxides, arsenic sulphide and other chemicals.

CATH CLEMESHA

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PLACES OF ENGINEERING INTEREST ON USA TRIP 1996

We were fortunate to have Ivan Dyreng as our leader. He had lived much of his life in Utah and knows this State and surrounding States intimately. Ivan organised the trip such that we saw places of interest including engineering ones as well as locations of geological relevance.

1. **Idaho National Engineering Laboratory**

We were able to have a lecture and self-guided tour of the **Experimental Breeder Reactor -1 (EBR-1)** [The young man who took us round the display and ably fielded all the questions we threw at him was in fact a veterinary student earning some extra money in his vacation. Ed] This reactor became live on 20 December 1951 and produced electricity for the next 13 years. The lecture explained how Uranium 235 was used in a chain reaction to produce heat which was carried from the reactor by liquid metal; a combination of sodium and potassium (NaK). This liquid in turn heated water to create steam which drove the turbine/generator.

Uranium 235 produces neutrons which are absorbed by Uranium 238 atoms and converted into Plutonium 239 which is a good reactor fuel. The reactor is called a "Breeder" since it produced more Plutonium than it consumed.

This nuclear reactor was the first in the world to generate useable amounts of electricity. It is situated about 25 miles SE of **Arco**.

2. **The Montana-Yellowstone Earthquake of 17 August 1959**

We stopped at **Hebgen** in the **Madison River Canyon** in order to see the location of a huge landslide which was initiated by an earthquake. 80 million tons of rock and debris flowed into the canyon forming a dam which created **Earthquake Lake**. In order to prevent a collapse of the dam formed by the landslide a 4 m wide channel was excavated across the 1½ miles of the slide to release the impounded water before it rose too high. The Army Corps of Engineers then found this unsatisfactory and dug out a second channel 15 m deep across the top of the landslide. This work was completed two months after the earthquake and removed the risk of a flood catastrophe downstream of Hebgen.

The earthquake rated at 7.8 on the Richter Scale affected a large area. Twenty-eight people were killed in the Madison River Canyon. It created tidal waves or seiches on Hebgen Lake which flowed over the dam. The regime of geysers in **Yellowstone National Park** was altered changing their playing times and eruption intervals.

3. **Thistle Landslide**

Thistle was a small village SE of **Utah Lake**. On 10 April 1983 after a year of high precipitation which raised water levels an ancient landslide became waterlogged and slid into the canyon where two creeks converge. We stopped on a rerouted Highway US6 climbing to **Soldier Summit** (9,959 feet) for a sight of the landslide into the canyon below. The slide kept moving for several weeks creating a lake 3 miles lang and 200 feet deep. However the material was not stable enough to act as a dam so a tunnel was driven on the north side of the canyon in order for the river to be diverted round the landslip zone. A further two tunnels were driven so as to realign a railway above the level of the lake.

4. **Teton Dam**

We were taken to **Teton,** NE of **Idaho Falls,** where there are still signs of flood damage created when the Teton Dam failed in 1976. It is reputed to be the worst civil engineering failure of a dam in the world this century. We had a great view of the remains of the dam which was constructed in a gorge cut through fissured rhyolite, a very unsafe volcanic rock. The core of the dam which created a watertight skin was badly deformed as we could see from our observation platform overlooking the river. This core was made from locally obtained loess instead of a more plastic clay. In addition the slope angle of the embankment looked too steep for the material used.

5. **Flaming Gorge Dam**

Construction of this dam began in 1958 to form part of the Colorado River Storage Project. It is built on the **Green River** in Utah. The dam is a thin concrete arch dam 503 feet maximum height and created a reservoir 91 miles long northward. There are three generators below the dam having a capacity of 150 megawatts.

The dam construction was completed in 1964 and, like nearly all the dams built for impounding water in the USA, was designed and fabricated to a very high standard. We stopped here long enough to walk along the crest of the dam and admire its location and construction.

6. **Glen Canyon Dam**

This structure also forms part of the Colorado River Storage Project. We were fortunate to have a long stop at this structure to visit the **Carl Hayden Visitors' Centre** located two miles from Page, Arizona. After studying the exhibits at the centre we progressed to the crest of the dam through a rock tunnel 181 feet long. We then descended 528 feet in a lift within the dam to its foot to reach the power plant where eight turbines have an installed output of 1,288 megawatts.

Lake Powell was created by the arch dam, which when full at an elevation of 3,700 feet above sea level, is 186 miles up the Colorado River. Construction of the dam commenced in 1958 and completed in 1964.

7. **Cane Creek Potash Mine**

This mine is located 7 miles SW of **Moab**, Utah, beside the **Colorado River**. The potash is extracted from the **Paradox Formation** which is part of the **Pennsylvanian System** formed 300 million years ago. Fresh water is pumped from the Colorado river to 2,500 feet depth, flows through old underground mine workings and dissolves the potash minerals. The solution is pumped to solar evaporation ponds on the surface to produce brines which are then processed in a special plant. A branch railway transports the potash which is used for fertilisers, chemical products and pharmaceutical products. We had good views over the ponds from **Dead Horse Point** to the north.

8. **Bingham Canyon Mine**

Mining for the ore which then contained 2% copper commenced in 1906. The mine has been worked ever since and is now the largest man-made excavation being half a mile deep and 2½ miles across. We stopped at the visitors' centre overlooking this huge hole where the history and method of mining were illustrated.

The mine removes 320,00 tons of material daily half of which is ore, the rest being overburden. The concentration of copper in the ore is now 0.6%. 2,100 people operate the mine by blasting the rock crushing it to a powder then concentrating it using water. This 28% copper concentrate is then smelted to produce "anodes. These anodes are refined by an electrolytic process to produce 99.99% pure copper. This process also recovers gold, silver and molybdenum.

DAVID STEPHENS

Fun finding erratics

By Cyril Dutton

WALKING ALONG some of the beaches of the east coast you will find a number of erratics along the shores. They are pebbles of various sizes and of various kinds of rocks. They were transported during the Ice Age by huge sheets of ice from a variety of places: the Lake Disrict, the Pennines, Norway and other parts of Scandinavia. If boulder clay is in the vicinity you can expect to find an interesting variety of erratics.

There are two places where you will have fun: the beaches below the cliffs close to Cromer (North Norfolk), and beaches below cliffs in Yorkshire where there is boulder clay. Between Flanborough Head and Sowerby Steps; also between Hornsea and Aldborough.

Two very interesting rock types are Shap granite which is pale pink, and larvikite which is medium or dark bluish grey. These two have been selected not only because they are both coarse-grained plutonic rocks, but because they are special: they are two distinctive rock-types which we can be sure of their place of origin.

The pimple called Shap granite

Shap granite, of course, came from the small outcrop of granite near the Lakeland town of Shap. And larvikite came from the rocks around the Norwegian town of Larvik. Because I am sure you are very familiar with the Shap granite, I will write about this only briefly.

Shap granite is a leucocratic plutonic rock which is often used for decorative purposes and can be found in many cities of the UK. In London, for example, it has been used to make bollards to designate the boundary of St Paul's cathedral. Once you know its characteristics, it is one of very few rocks you can be sure of its source.

The exposure of granite in Cumbria is but a small pimple of rock upon a very large granite mass which extends over a wide area of the Lake District. As you will already know, its formation is related to the closure of the ancient Iapetus Ocean which prior to that event separated Scotland from England.

Caution because of IRA

The last time I visited the quarry on Shap Fell, a security guard prevented me from entering. Presumably because of IRA activity. But on previous occasions I was able to enter and inspect the quarry face and its rocks. One piece displayed the distinctive "repekivi" texture (Figure 1). This name is given to a feldspar phenocryst involving the growth of a plagioclase mantle (A) around an alkali feldspar core (B). Now I will switch to the larvikite rock, named after the town of Larvik (Figure 2), which has a much more complex and interesting history.

Figure 1

As we walk along our shore and pick up a larvikite erratic which has been delivered by ice sheets from Norway during the Ice Age we ponder its fascinating colouring, its volcanic origin, and where and how it originated. If only we could have witnessed this fascinating volcanic activity during its formative period ourselves! Without doubt it, would have been a fantasy to remember.

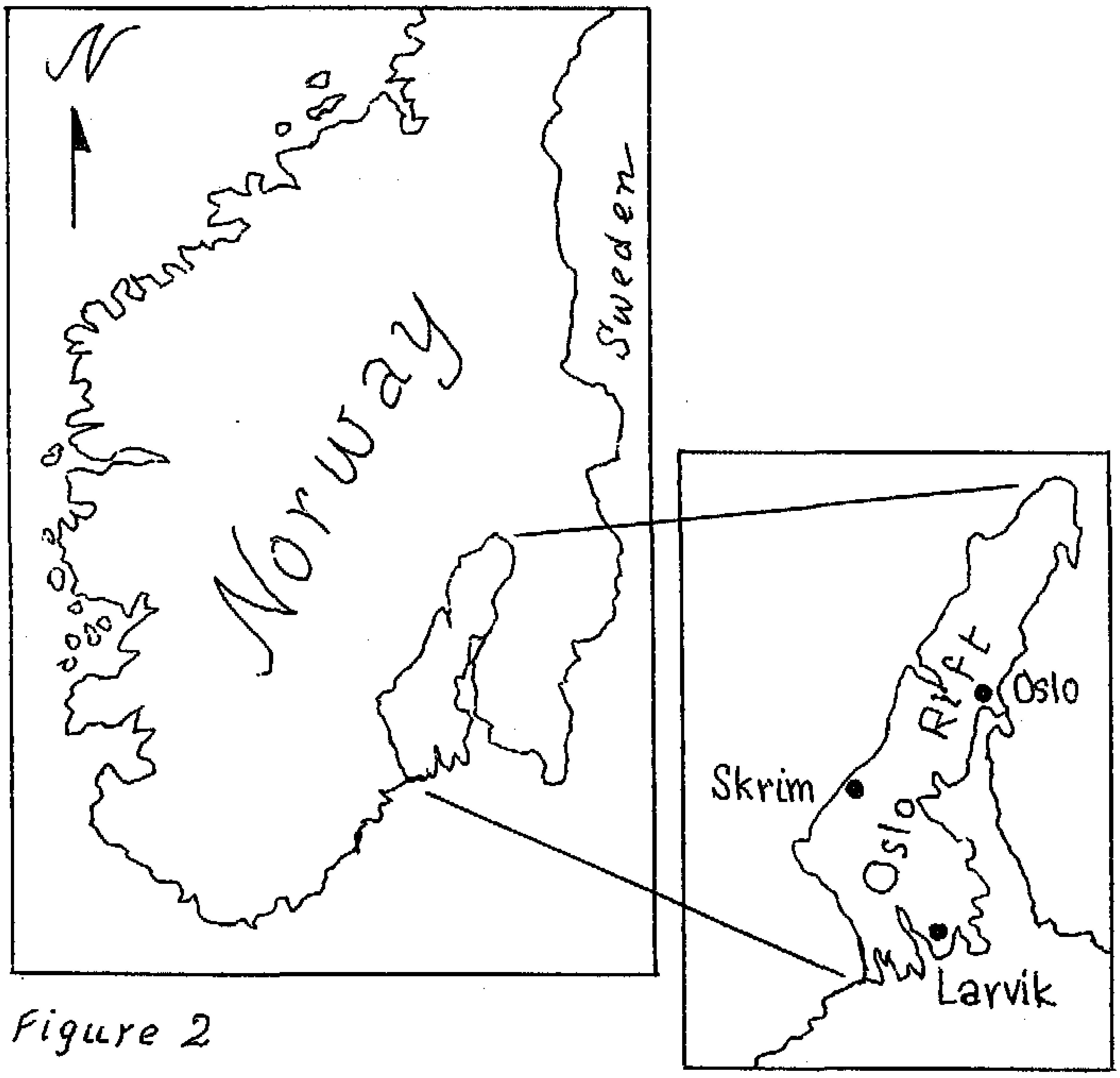

Figure 2

We would have enjoyed the experience

But of course, we humans did not exist during the Permian. And one would indeed need a lifespan of some millions of years to be able to observe the entire dramatic sequence.

Perhaps we can *try to satisfy ourselves* by *creating a mental picture* of what happened. Firstly, let us consider Norway at the start of the Permian. While most of the rocks along the southern part of Norway and Sweden are various gneisses of Precambrian age, the rocks of the Oslo rift are exceptions. Long before the volcanism of this region began, the area was covered with sediments of Cambrio-Silurian age. This material had been washed down by the huge rivers draining from the eroding mountains in the north. These mountains were built during the Caledonian orogeny.

The present-day city of Oslo is built on the rocks of the Oslo Rift (Figure 2). But this rift is not like any ordinary rift. It is not like the neat and simple great Rift Valley of East Africa. Within the Oslo Rift zone it was more like a "basin and range" terrain, and that is why it is often called Oslo Rifts in the plural. It is approximately of the same age as the Midland valley of Scotland, and its volcanic activity is commonly known as of **Permian** age. Yet the initial effusive volcanism began about 295 Ma. That, of course, was about 15 Ma *before* the Carboniferous/Permian boundary which is dated at 280 Ma.

An Iceland-type experience?

The first lavas to pour out were effusive basalts. This effusive display, like that of Iceland today, would indeed have been a delight to watch. It is well-known that a release of pressure plus the addition of water reduces the temperature at which the mantle rock becomes subject to partial melting. And this, of course, produces basalt. This rifting would certainly have provided both of the above requirements.

Next, we may ponder the point where this activity began. It started in the area close by the present-day town of Skrim, which is located along the western edge of the Oslo Rift (Figure 2). This effusive activity introduced the major volcanic phase which lasted for at least 3 Ma. However, some workers believe it lasted as long as 11 Ma.

A 150 m thick pile?

Today geologists have divided the rift into two zones: the southern one is called the Vestfold, where the early basalt pile reached a thickness of 120 m to 150 m. The northern zone is called the Krokskogen plateau where the lava pile was between 20 to 30 m thick and here the rocks consisted of tholeiitic basalts. And naturally, with time, the basalts of the Vestfold gradually up-graded into alkali basalts.

How it evolved

Following the alkali basalts, the lavas evolved into rhomb porphyry flows and these covered the entire plateau of the Oslo Rifts. Plutonic activity produced two large and composite batholiths of syenite, monzonite and granite. The southern batholith is the earlier of the two and its rocks are dated 286 to 275 Ma, while the rocks of the northern one are dated a little later at 280 to 260 Ma.

It is estimated that over 20 cauldrons existed in an area of about 10 000 km^2 in the vicinity of Oslo. These cauldrons were 5 to 15 km in diameter, and later within them younger volcanic cones developed. We also know that there was a final outpouring of ignimbrite material since the Ramnes caldron has a thick sequence of preserved ignimbrites to prove it. These, as you will know, are more characteristic of explosive volcanoes at island arcs, but in any case, it signifies the late, or final phase.

Today, researchers have counted six basaltic flows which they number B1 to B6, and say they must have covered 220 km². The rhomb porphyry flows number RP1 to RP26. These covered as much as 1160 km².

Late-stage ignimbrites extensive

In addition, the late-stage activity of the volcanism, which extended far beyond all previous flows, would have produced a thickness of 1400 m of massive ignimbrites. The larvikitic plutons below extended over an area of about 1700 km².

As would be expected in a tensional zone of crustal extension, there are numerous igneous dykes. There are as many as 1500 dykes in the Oslo area alone. These follow the major fault trends: one trend is just a little west of due north; the second trend is ENE-WSW.

Was it a triple junction?

In broad tectonic terms, the Oslo Rift is assumed to represent a failed arm of a triple junction. But this is not proved. The centre point is thought to be in the North Sea according to Burke & Dewey (1973). The visible length of the rift in Norway is 200 km, and it is assumed a further 200 km extension lies below the sea in a southerly direction.

Larvikite occurs in the region around Larvik and Skrim. Around Skrim is where the oldest larvikite is found. If one uses the classification normally used for granites, it could be regarded as an I-type rock since it is derived from igneous material.

Group of syenitic plutonic rocks

Larvikite being a syenitic plutonic rock, the most common minerals are alkali feldspars and these can be up to 90 per cent. Although syenites are normally leucocratic, they can sometimes be mesocratic, being either shades of white, pink or red. It is interesting that the type area is Syene (Aswan) in Upper Egypt.

Syenites are relatively uncommon rocks world-wide, but one particular type, larvikite, is well known. It is commonly used as a facing stone on buildings in some of our large cities. Larvikite comes in two main rock colours: the mesocratic blue to pale grey, and the melanocratic darker grey to blue.

Fascinating schillerization

When polished, the feldspars in larvikite show a beautiful play of light which is known as the "schiller effect". This schillerization is due to light reflected from the silvery blue feldspar crystals. When we remember that aluminium ions can replace silicon ions in this rock, the brilliance of this reflection becomes understandable.

Syenites have dominant alkali feldspars of at least 65 per cent and can be up to 90 per cent of the total feldspar. But some larvikites are classified as monzonites because they have about equal amounts of alkali feldspar and plagioclase feldspar.

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BOEING DISCOVERS NEW ELEMENT

The Heaviest element known to science was recently discovered by Boeing physicists. The element, tentatively named Administratium, has no protons or electrons and thus has an atomic number of 0. However, it does have 1 neutron, 125 assistant neutrons, 75 vice neutrons and 111 assistant vice neutrons. This gives it an atomic mass of 312. These 312 particles are held together by a force that involves the continuous exchange of meson-like particles called morons.

Since it has no electrons, Administratium is inert. However, it can be detected chemically as it impedes every reaction it comes in contact with. According to the discoverers, a minute amount of Administratium caused one reaction to take over four days to complete when it would have normally occurred in less than one second. Administratium has a normal half-life of approximately three years, at which time it does not actually decay but instead undergoes a reorganisation in which assistant neutrons, vice neutrons and assistant vice neutrons exchange places. Some studies have shown that the atomic mass actually increases after each reorganisation.

Research at other laboratories indicates that Administratium occurs naturally in the atmosphere. It tends to concentrate at certain points such as government agencies, large corporations and universities and can usually be found in the newest, best appointed and best maintained buildings.

Scientists point out that Administratium is known to be toxic at any level of concentration and can easily destroy any productive reaction where it is allowed to accumulate. Attempts are being made to determine how Administratium can be controlled to prevent irreversible damage, but results to date are not promising.

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