Glarus and Moine

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Flims is an Alpine town little known to British walkers and climbers, so why did I search it out and go there? First, when reflecting on where I might spend a few days walking in the Alps, I thought it would be interesting to see the mighty river Rhine in its more youthful stages, where it was just an ordinary small river winding its way along. Perhaps it is not well known that the Rhine is credited with two sources from which flow the Vorderrhein and the Hinterrhein, in the Swiss Canton of Graubunden (also known as Grisons). These two rivers join at Reicheneau, west of Chur and after bypassing that town the fully formed Rhine flows north into the Bodensee (Lake Constance). It exits the lake heading west as the High Rhine but soon becomes the familiar Rhine which flows north and, after a total journey of more than 750 miles, it enters the North Sea through a complex delta near Rotterdam. Flims, I learned, is close to the Vorderrhein. Then I also learned that Flims is the site of a mighty rock slide which occurred 9000 years ago. It blocked the Vorderrhein which subsequently cut its way through, creating the Ruinaulta gorge. Better and better I thought. And finally I learned that Flims was a good base from which to see the celebrated Glarus Nappe, the most important geological site in the Alps and something I had long been keen to see. The towns of Glarus, Elm and to the south, Flims, all provide a base for walks enabling a close up inspection of the Nappe, which is central to this article.

Flims comprises two villages straggling along the upper slopes of the Voderrhein valley, Flims Dorf and Flims Waldhaus. They form a pleasant but not particularly picturesque small town which actually sits on the upper part of the stabilised rock slide, now a mixed forest about forty square kilometres in area. To the north, above Flims, are the Glarus Alps, attractive Alpine scenery.

To see the young Rhine, the Vorderrhein, in its innocent stage of meandering in a pastoral setting, I went west from Flims to the village of Falera. This classic Alpine village of great charm is located by a spur projecting out over the Vorderrhein valley and upon which there is both a very fine church and, on a grassy slope, an array of

Figure 1 *The Tschingelhoren, with the shallow angle Glarus fault clearly visible. The dark rock above the fault line is 250 - 300 million years old and below the fault lies lighter coloured rock which is 35 – 50 million years old. The hole in the wall, the Martinsloch, is visible below the fault.*

megalith circles, which is exceedingly rare in the Alps. So interesting were the megaliths and the church that they competed with the viewpoint offered by the spur. However, the view of the Vorderrhein meandering its way along the valley below was greatly enjoyed, and photographed.

To see the Vorderrhein cutting its way through the gorge to the east it was necessary to walk through the forest, now well established on the gently undulating surface of the rock slide, and access a viewing tower built to project over the gorge. The sight thus obtained was impressive, raw and savage. The river meanders have undercut huge ugly screes. Chaos was the word which came to mind after savage, and it applied particularly to the upper sections of the walls of the gorge, which provided a cross section of the original rockfall. Yet despite a dreadful instability apparent in the gorge-scape, the railway line and bridge, which could be seen in miniature way below, looked safe enough, as indeed they are, conveying the Glacier Express from Chur to the east to Andermatt and beyond to the west.

Now for the Nappe. Standing in Flims with your back to the forest and the Vorderrhein, the view north up to the mountains is pleasingly Alpine. On the right lies a massive limestone wall which accommodates a celebrated Via Ferrata climb, and on the left forested slopes descend gracefully. Straight ahead lies a broad ascending valley, narrowing with increase in height. In the far distance an array of spectacular pinnacles, the Tschingelhoren, can be seen. The highest mountain, the Piz Sardona (3056m) is in the vicinity, but not dominant. To get up to the interesting high ground without wasting energy I used the first chair lift, straight off the main street, followed by a second lift and finally took a somewhat antique looking cable car to Cassensgrat (2637m). A tiny restaurant at the top station tempted me to try the goulash, which was excellent, after which I started exploring. The domed top was stoney and naturally barren but a splendid 360 degree viewpoint. It was the start of numerous walks, some quite demanding, others less so but they shared a dramatic landscape. I headed north west to get a good view of the Tschingelhoren, (Fig.1). This is a wall which rises from screes and thrusts upwards half a dozen or so pinnacles. Running across the base of the pinnacles and well above the scree line there is a sharp line incised in the rock wall. Anyone would regard it as a fault line and indeed it is, one which has been studied for over 150 years. I descended a scree path into the corrie-like amphitheatre at the base of the Tschingelhoren to take a closer look.

We are here concerned with mountain building and the folding of the earth's crust which that entails. The word nappe, table cloth in French, gives a clue as to how the process was first modelled. First clear the table and then place your hands flat on the table cloth. Move them slowly together and the cloth wrinkles and then folds. Then as the folds grow they topple over to one side. Translate that to the earth's crust and you have the beginning of an explanation for crustal folds. In the early days of the science of geology it was quite reasonably assumed that young rock always lay on top of older rock. However, examples were discovered which appeared to contradict that assumption, as in the Glarus Nappe. This was a serious problem, but on reflection we can see how the table cloth model, with its toppled folds, provides an explanation of how old rock can come to overlie younger rock. Furthermore, it was established that the earth's crustal folds and nappes could be subject to a shearing process, in which the top of a set of nappes is ripped away, laterally, and moved tens of kilometres before coming to rest on top of mis-matching folds. Such processes took place very deep in the crust where the high temperatures and pressures alter the mechanical and chemical properties of the rocks. Over time erosion then does its stuff and all is revealed, well sufficient for geologists in the 19th century to piece the basis of this story together. The clear fault line running across the Tschingelhoren is a spectacular example of a low angle thrust fault along which nappes have been displaced horizontally, some 30 to 40 km. The upper section comprises a dark Permian rock called Verracano which is 250 – 300 million years old. It lies on top of rock which is only 35 – 50 million years old. Sandwiched between the two is a thin layer of material which functioned as a lubricant, the Lochsitencalc. The fault arose about 25 million years ago, ie in the Oligo – Miocene Epoch, during the building of the Alps. The plane of the fault slopes gently up towards the south and there are many exposures throughout the 300 square kilometres of the Unesco World Heritage Site which the Swiss have secured to preserve the area.

The Tschingelhoren is also notable for the Martinsloch, a hole about 15 metres in diameter, visible in the photograph. It is quite irrelevant to the important geology close by, but it does demonstrate that the wall is a very thin partition and provides walkers with an intriguing focal point as they ascend the scree path to the Segnas Pass (2627m). I was not organised to cross the pass so I turned and began my return to base.

It was an interesting walk down to the Plaun Segnes Sut, an alluvial outwash plain into which, on the eastern side, cascaded a splendid waterfall. On the west side rock slabs arose which provided a climbing school with a convenient set of graded pitches. Beyond there was a grassy alp to be traversed which led down to the bottom station of the cable car and the top station of the chair lift. When I was half way across the alp the weather changed abruptly as dark clouds gathered on the tops and a rainstorm could be seen sweeping along the valley below. The first crack of thunder startled me and I should have been ready for it. The rain hit hard and cold. The lightning was quite frightening and I tried to remember what to do with my metal walking pole. At least the handle was insulated. By the time I had gone through the pros and cons of this and that course of action to protect myself, with several lightning strikes uncomfortably close, I reached ground beneath the car cables. They would screen me, I thought, and so arrived at the chair lift top station in a more relaxed frame of mind. A few walkers were already waiting there, looking cold and miserable in their skimpy Alpine summer shorts. We had to wait for the storm to pass and the chair lift to re-start. Snuggling in my Scottish summer kit of Gortex and woollies I enjoyed the ride down and started to think again of the history of the famous Nappe and thrust fault I had just seen.

In the 19th century the Swiss geologist Arnold Escher explained the "old rock on top of young" phenomenon seen in the Glarus Nappe more or less correctly, as above, but changed his mind in favour of another model, which was unfortunately wrong. The correct explanation was eventually put forward by Bertrand and Tornebohm. Here I have provided only the simplest of summaries because the Glarus Nappe complex is indeed just that, complex, and research on important details continues (Amateur geologists see www. geopark.ch and Swiss J. Geosci. **101**, p323 -340, 2008).

Nappes are not rare. Mountains are made of them including those close to home. In the 19th century the North West Highlands of Scotland were intensively studied because, among other things, the phenomenon of "old rock on top of young" was thought to be present, especially by James Nicol of Aberdeen University. Contrary to the established view he was convinced that the Moine schists overlay younger Durness Limestone. A major study by geologists of the Geological Survey of Scotland was initiated in 1883 and concluded that it was along a thrust fault, the Moine Thrust, that the Moine schists had indeed moved many tens of kilometres, from east to west, coming to rest on top of the Durness Limestone.

The SNH site of Knockan Crag some 13 miles north of Ullapool on the A835, provides an excellent exposure of the Moine Thrust and the shear zone along which movement took place. You can also hear a nice recorded conversation between seated effigies of the two geologists, Ben Peach and John Horne, who were most prominent in developing the radical new understanding of how the earth's crust behaves. Every walker and climber should make a pilgrimage to Knockan Crag.

It is difficult to grasp the originality of the folding, thrust and shear processes which Peach and Horne proposed to explain the surface geology which they had painstakingly mapped. However, it was easy to see objections to the idea. Where did the energy for such colossal events come from? Did the lateral displacement of the crust cause the earth to shrink in diameter? We now know that the earth's crust is made of discrete units, tectonic plates, and that geothermal convection currents below the crust drives the plates into each other, wrinkling the crust into folds and nappes. Fresh crust spreads out from the middle of the ocean floor so the earth does not shrink. The Glarus Nappe arose from the collision of the African plate with the European plate in the creation of the Alps. In the case of the NW Highlands the story is more ancient and complicated, but the Moine Thrust and the other associated faults were also the result of tectonic collision.