

LATE 18TH AND EARLY 19TH CENTURY FORAYS INTO ECONOMIC GEOLOGY – SOME LITTLE KNOWN FRANCO-GERMAN PAPERS DESCRIBING CARCLAZE OLD TIN PIT, NEAR ST. AUSTELL, CORNWALL



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Carclaze Old Pit lies on the southern boundary of the St. Austell Granite about 3 km NNE of St. Austell. It probably originated from tin stream workings in the Sandy Bottom valley following a rich source of tin to the crest of the hill, where a massive stockwork consisting of a tin-bearing greisen-bordered quartz-tourmaline vein swarm, adjacent to the granite margin, was developed by an open pit. This was a 'must-see' site for late 18th and early 19th Century geological visitors to Cornwall and there are many accounts and illustrations describing the pit and the method of working. The earliest scientific account was by a Frenchman, M. Jars from the Académie Royale des Sciences de Paris, who visited the pit in 1764. This was followed by other Frenchmen: Bonnard in 1803, Dufrénoy and de Beaumont in 1824-7 and Daubrée in 1841. Von Oeynhausen and Von Dechen from Germany provided the first geological map and cross-section of the pit in 1829, showing the layout of the veins. These accounts show a considerable understanding of economic geology; they are reminiscent of what would be called a 'feasibility study' today. This suggests that, in parallel with the development of stratigraphic geology and palaeontology mainly led by British geologists, there was a development of metalliferous economic geology, mainly led by French and German scientists. The earliest account of the pit by an English author was by Adam Sedgwick in 1822; in later publications in 1831 and 1835 he speculated on the formation of parallel vein swarms and schorl rock, partly based on his observations in Carclaze Old Pit. De la Beche provided a pen and ink sketch of the south face of the pit in 1839. Tin extraction from the Old Pit had practically ceased by the mid 19th Century as production switched to china clay. These accounts also show how the technology of the early china clay industry evolved from large scale open pit tin operations.

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INTRODUCTION

The aim of this paper is to describe the role that Carclaze Old Tin Pit near St. Austell played in the early development of geological science, particularly the economic aspects, and in pioneering open pit mining technology. The pit was very much a 'must see' location for late 18th and early 19th Century travellers and there are numerous accounts and illustrations of it which, at that time, was one of the largest open pit excavations in Cornwall and one of the few locations, apart from coastal exposures, where mineral veins could be seen in daylight. Many of the earliest papers describing the geology and mining methods, published when the study of geology was in its infancy, were by French and German authors. Indeed, a Cornish Fellow of the Royal Society, John Hawkins of Trewithen, spent long periods at mining schools in Germany in the late 18th Century, with the avowed intention of bringing back to Cornwall the latest knowledge of mining and mining geology (Cleevely, 2000).

Carclaze Old Pit lies on the southern boundary of the St. Austell Granite about 3 km NNE of St. Austell (Figure 1). Archaeological finds from the valley alluvials on the south side of the granite, notably in the Par and Vinnick (White) river valleys, indicate they were first worked for tin in the Bronze Age (Penhallurick, 1986). Within the catchment of the stream which flowed down Sandy Bottom there was strong tin mineralization, later worked underground by Charlestown United mine, so the alluvials in this valley would probably also have been exploited by tin streamers from early times. As they worked their way up Sandy Bottom (Figure 1), they are likely to have encountered a rich source of tin which grew stronger

the further up the valley they progressed. Their openwork followed this source to the crest of the hill, where a massive stockwork consisting of a tin-bearing greisen-bordered quartz-tourmaline vein swarm adjacent to the granite margin was developed by an open pit, which local tradition says dates back to Tudor times. In the late 18th Century this was known as Parnell's Stream-work (Gilbert, 1817; Drew and Hitchens, 1824), but later became known as 'Carclaze Old Tin Pit' or simply 'Carclaze'.

Extensive engineering works in the 18th Century were needed in order to provide an adequate water supply for power and process water to the pit, with a system of leats bringing water from 3.5 km away on the southern slopes on Hensbarrow. In the 18th Century ore from the Old Tin Pit was removed in a chain of small barges through an underground canal under the pit bottom, connecting to the valley 500 m to the south. This could be the earliest underground canal built in Britain and it has recently been rediscovered. Sand and clay were removed through a separate drainage adit; later in the 19th Century the old canal tunnel was converted to a tramway.

If accounts by Hunt (1884) and Symons (1881) are to be believed, a very large quantity of tin was extracted, equivalent in value to approaching £100 million at the present (October 2008) tin price of US\$14,000/ton. This suggests that Carclaze old pit was one of the richest stockworks ever exploited in Cornwall. In the latter half of the 19th Century tin production declined, to be replaced by china clay, and the workings at Carclaze extended northwards to form two new china clay pits called 'Old Baal' and 'New Baal'.

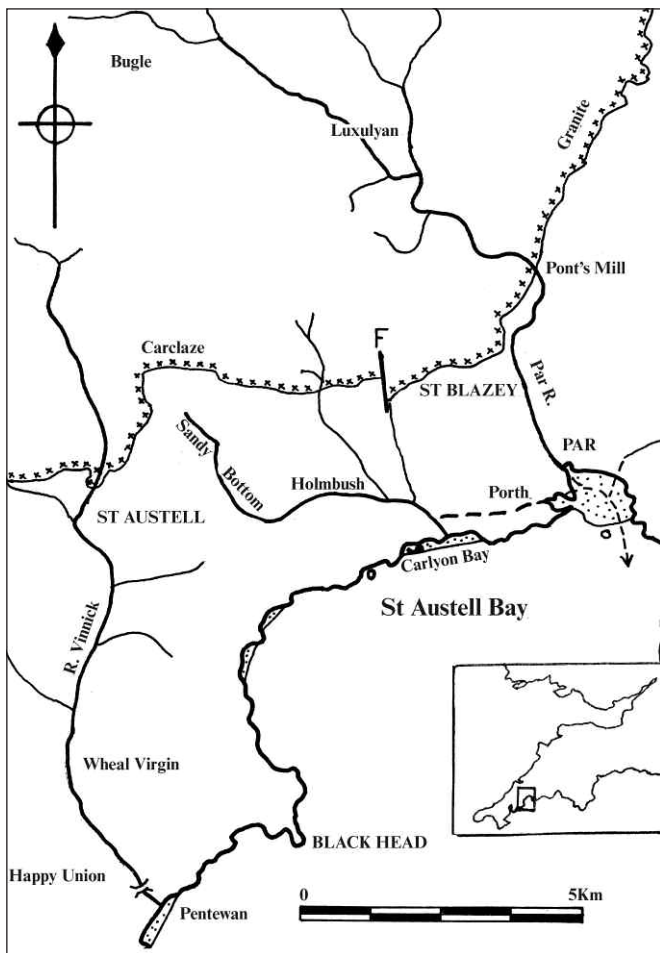


Figure 1. Sketch map to show the location of Carclaze and other tin mining operations in the St. Austell area.

THE OREBODY

The cross-section (Figure 2), published by Collins (1878), shows the general arrangement of the orebody. Numerous parallel greisen-bordered quartz-tourmaline veins, striking east-west dip southwards, approximately parallel to the granite margin, passing outwards into strongly tourmalinized rocks of the metamorphic aureole, which Collins (1878) called 'tourmaline schist'. Further away from the margin this becomes slightly hornfelsed Lower Devonian slaty mudstones and siltstones belonging to the Meadfoot Group. Some more steeply dipping east-west veins were noted by Dufrenoy and Elie de Beaumont (1826), Von Oeynhausien and Von Dechen (1829) and Collins (1878); both sets of veins were tin bearing; rich bunches of ore were found at the intersections of the two sets of veins. The granite in between the veins is kaolinized and the slaty rocks of the aureole also contain some irregular bands of kaolinization.

A photograph of the south face of the Carclaze Old Pit taken in 2007 shows the parallel veins (Figure 3). A closer view of one of the veins in Baal Old Pit (Figure 4) shows the central fracture along which the mineralizing fluids passed, marked by a black quartz-tourmaline leader, with the wall-rock alteration of greisenized granite on either side. The tin was mainly contained in the quartz-tourmaline leader as cassiterite (Figure 5), but the greisen usually also contained sufficient tin to make it worth pulverizing in stamps. The kaolinized granite between the veins also contained some cassiterite, which could be recovered with little or no stamping. The mineralization was said by Von Oeynhausien and Von Dechen (1829) to be similar in style to Cligga, and by Daubr e (1841a) and others to St Michael's Mount. However, unlike Cligga, only very small quantities of tungsten and zinc ore were recorded from Carclaze.

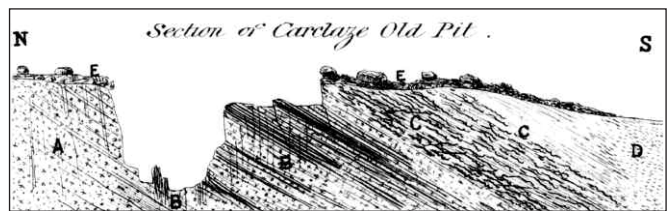


Figure 2. Cross-section of Carclaze pit taken from Collins (1878). (A) Rather Hard Granite with thin schorl veins, some dipping south others vertical. (BB) Clay Rock (Carclazite) with many thick & thin schorl veins, with veins of quartz & Greisen. (CC) Tourmaline Schist, gradually passing into D. (D) Reddish & Brownish Killas. (EE) Overburden, containing and capped by loose boulders.



Figure 3. View of the south face of Carclaze Old Tin Pit, looking east. The granite/metamorphic aureole contact is near the top of the face. The parallel greisen-bordered quartz-tourmaline veins can be seen right of centre. The face is about 30 m high and is the same face as was photographed by the Geological Survey in 1905 (Figure 10).



Figure 4. Close-up of a greisen-bordered quartz-tourmaline vein at the north end of Old Baal. A quartz-tourmaline leader is in the centre of the vein, flanked by greisen borders. The penknife (9 cm long) rests on partly kaolinized granite.

A number of the early authors comment that the lodes in the pit change their character towards the surface; Drew and Hitchens (1824) say: "In this mine the lodes are numerous, but not large, and as they approach towards the surface, the directions they take are so various, doubtful, and indefinite, as to furnish strong indications, that through some grand convulsion of nature, the whole surface has been in a kind of fluid state". Bonnard (1803) made similar comments. Sedgwick (1831) describes "veins of segregation" composed of irregular masses of schorl rock in the clay pits around Carclaze, which he distinguishes from the more normal veins. Borosilicate masses (schorl-rock) are found in many china clay pits and have a tendency to develop into tourmalinite breccias.

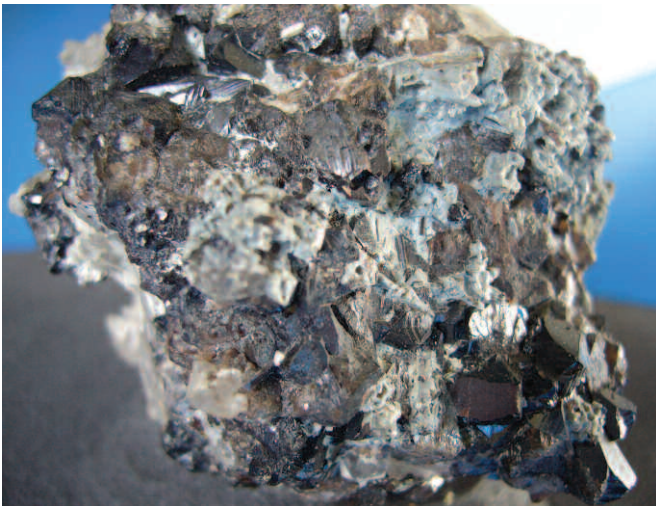


Figure 5. Photograph of a specimen of cassiterite from the collection of the Royal Institution of Cornwall. The original label reads: 'Tin from Carclaze Mine found Feb. 1796'. Mr. R. Cleavelly (personal communication, 2007) believes the handwriting on the label is possibly that of John Hawkins FRS who is known to have supplied specimens to Philip Rasbleigh for his collection. The specimen shows nicely formed prismatic crystals of cassiterite set in a matrix of a white porcellanous material, which is probably kaolinite. Some thin needles of tourmaline are also present. Tin in run-of-mine ore would probably have been finer grained than in this specimen, which is 6 cm across.

EARLY ACCOUNTS OF CARCLAZE BY FRANCO-GERMAN AUTHORS

The earliest account of Carclaze was by Jars in his '*Voyages métallurgiques*', published in Paris in 1781. Jars visited many of the known mining regions of Europe in a series of tours in 1758, 1764-5 and up to 1769. Cornwall was visited in 1764 and places visited included streamworks around St. Austell, Carclaze, Pednandrea mine in Redruth and Godolphin Mine near Helston. Although Carclaze is not named, the description leaves little doubt that Jars visited Carclaze in the summer of 1764, as the paper contains a description of the quarry and the underground canal, which correspond with later descriptions of Carclaze. Jars began his Cornish section with a general description of the area and stated that tin is found in three types of deposit: (1) veins, (2) stream works and (3) a type which combines some of the characteristics of (1) and (2).

He allocates Carclaze to Type 3 and mentions the general view at that time which attributed stream tin deposits to the biblical deluge, but disagrees with this; instead, he suggests many of these deposits could have been formed from the rubbish produced by ancient mining activities. In fact, this was probably true, as we now know (Penhallurick, 1986), that many 18th and 19th Century tin streaming operations were working deposits first worked in Bronze Age times.

Jars reports 'the rock is of granitic character, whitish in colour and very friable, containing throughout small quantities of tin mineral'. He likened the occurrence to what the Germans call a 'stockwerck'. He says the tin occurred in an 'infinite' number of small parallel black veins striking east-west and that the matrix was easily dug using a pick and other iron tools. Most of the tin was said to occur in the veins, which were sometimes quite rich.

There then follows a description of how the pit was worked. Water was brought into the quarry through a level which discharged into the lower part of the pit, and was then distributed to the softer areas where workmen broke down the matrix to a sand (what would probably today be referred to as 'slurry'). By gravitational settling and the use of special shovels (probably what today would be called 'vanning shovels') the tin was recovered. That which could not be dispersed by the water

Late 18th and early 19th Century forays into economic geology

(mostly vein material) was broken down with sledge hammers and then transported to the stamps in small boats along a canal half a league in length (1 French league = 3 English miles, so this is an overestimate, as we now know the canal was 500 m in length). Jars says the canal was two fathoms (4 m) above the drainage adit, which took away the slurry for further processing in the valley.

Jars then discusses the economics of the operation and comments that the canal is important as it enables the immense quantity of ground forming the stockwork to be removed without having to be raised 8 to 10 fathoms (14.6-18.3 m) to the surface. Clearly, when the only source of power was human, animal, wind or water, this was important. The waste debris was carried away by the stream of water through the drainage adit. Later accounts suggest that this material was also treated at Phernyssick (in the area formerly known as Carclaze yard, but recently developed as a housing estate) to recover some tin. Gunpowder is said to have been unnecessary in the open pit although, as the orebody became harder at depth, he says it would have been needed if this was to be exploited by underground working. Jars doubted whether this would have been economically worthwhile. He also reports that the construction of a deeper canal 8 to 10 fathoms (14.6-18.3 m) below the existing one had been talked about for many years, in fact this was never constructed. This is an important statement as it implies that the original canal must have been constructed well before the 1760s, which could make it the earliest underground canal constructed in Britain. The account by Gilbert (1817) also suggests an early date for the canal. Reading this old account, written nearly 250 years ago, brings to mind the kind of thoughts a present day industrial geologist would have in preparing to make a '*feasibility study*' for a mineral reserve assessment of an orebody like Carclaze.

The next account is by a Frenchman called Bonnard, based on a visit in 1803, which was published in the '*Journal des Mines*'. He identified the vein material and the kaolinized granite as different types of altered granite produced by the action of water on the more normal granites seen elsewhere in the pluton and reported that the clay was similar to the higher quality clay being worked several miles away, which was sent for porcelain manufacture in Staffordshire; he said that some of the Carclaze clay was used for coarser pottery. However, the main innovation since Jars' visit is that the stamps have been moved from the valley into the pit and were powered by 10 waterwheels. This suggests that the water supply had been substantially augmented since Jars' visit; research by Moore (personal communication, 2007) has identified an elaborate system of collecting areas and leats which brought water from 3.5 km away on the southern slopes of Hensbarrow to power the machinery in the pit, an early example of the use of renewable energy. A later lithograph by Mitchell dated 1841, from the Royal Institution of Cornwall collection, gives an idea of what the pit must have looked like (Figure 6). Although Bonnard described Carclaze as a 'great excavation 60 fathoms (110 m long, 30 (35 m) wide and 20 (36.5 m) deep', this is tiny by present standards, probably not much more than an acre (0.4 ha) in extent. Bonnard identified that a key economic factor was the purity of the concentrates, in common with the concentrates from tin streaming, which did not need roasting and further washing to remove contaminants such as metal sulphides and arsenides, which most underground mine concentrates at that time needed. So, as we see with Jars, Bonnard concentrates on identifying the key factors which made Carclaze economically viable.

The next detailed description is also by Frenchmen, Dufrenoy and Elie de Beaumont, who published three nearly identical accounts in 1824, 1826 and in a book entitled '*Voyages métallurgique en Angleterre*' in 1827. Their account is divided into separate descriptions of the geology and the mine. An engraving by Thomas Allom dated 1831 shows what the pit must have looked like at the time of their visit (Figure 7). The geological section is much more like a modern descriptive account of a mineral deposit. They described the two vein sets



Figure 6. Lithograph of 'Carclaze Mine' thought to have been published by Philip Mitchell in 1841 (reproduced by kind permission of Royal Cornwall Museum, Royal Institution of Cornwall), although it may depict a scene from earlier. Probably looking east; five waterwheels can be seen which are powering stamps, a discarded stamps barrel is seen in the right foreground and a sloping table on the right is being used to recover coarse tin. The movement of material in the pit can be seen to be by wheelbarrow.

and the detailed profile of a typical vein. For the first time tourmaline was identified as the black mineral forming the leader in the veins. They also described a green mineral in the veins which they called green talc, which is probably gilbertite. The technical description of the mine is rather more flowery and it is clear that the pit had now grown to around 5 acres (2 ha). However, there were only three waterwheels powering the stamps (Figure 7) and there is no mention of the canal with its boats. We know that, in the late 18th Century, the portal of the canal tunnel in the pit collapsed and it became disused (Gilbert, 1817). The deeper drainage level was still functional and the slurry was settled in basins at Carclaze yard and further processed to recover fine tin.

Two German authors, Von Oeynhausien and Von Dechen, included an account of Carclaze in a paper describing the contacts between the granite and the metamorphic aureole throughout Cornwall, published in 1829. Unlike the earlier French accounts there is no mention of the economic factors. However, for the first time, we are provided with a plan and section (Figure 8) of the working, although they are clearly idealized. The dimensions given suggest that the pit is similar in size to that described by Dufrenoy and Elie de Beaumont two years earlier. Importantly, they recognise that the alteration of the granite, including the kaolinization, had been accomplished by circulating waters *in situ*. Two sets of southward dipping metalliferous veins can be seen, one 22° north of west and the other 15 to 30° east of north, forming the typical conjugate set now familiar throughout the orefield. Barren non-tourmaline-bearing white quartz lodes trending 15 to 20° west of north are identified and are said to heave every tin lode they meet. Nowadays these cross-course lodes are recognised as a regular

feature of most china clay pits. The account of the mineralogy is fairly detailed and they report that the tin mainly occurs in the tourmaline leaders in the centres of the veins, together with some wolfram. The regular veining is said to give the rock a stratified appearance, bearing a strong resemblance to the veining at Cligga Point. In the cross-section (Figure 8b) only the drainage adit is shown, as the canal level was still out of action.

There are some further French papers by Daubr e (1841a, 1841b), but the general description of the geology at Carclaze is largely a repeat of what was said in the earlier French papers. However, one of the papers (Daubr e, 1841b) contains a fascinating discussion on the formation of fluosilicates and borosilicates and the role that tin fluorides played in the genesis of tin deposits. Considering the date, the understanding of the chemical processes involved is impressive. All this was based on his observations at Carclaze and various tin deposits in Brittany and Bohemia. Apart from some brief mentions by Carne and Hawkins in 1822, there are no further mentions by Cornish-based authors until the 1830s.

LATER ACCOUNTS BY BRITISH AUTHORS

In 1822 the Rev. Adam Sedgwick, one of the founding figures of geological science, described a visit to Carclaze: 'The enormous open work of Carclaze near St Austell is an object of no ordinary interest. The traveller may there see the operation of the miner carried on in the light of day, without being compelled to descend a hundred fathoms below the surface and then to crawl into a dirty dripping cavern. The works are excavated in a variety of stanniferous granite or schorl rock.... Throughout the whole extent of the excavation, we may trace

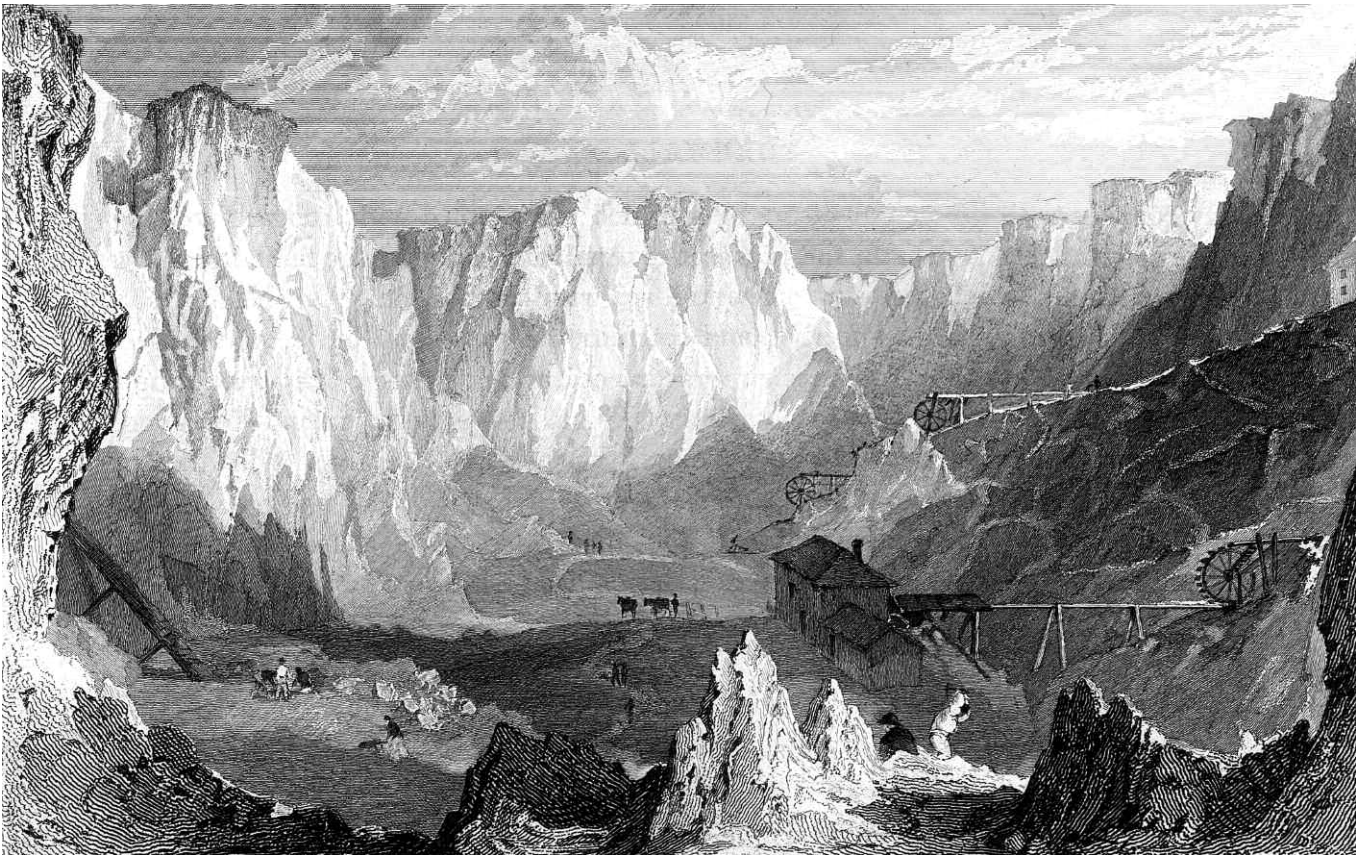


Figure 7. Engraving of Carclaze taken from Allom (1831) *Cornwall Illustrated in a Series of Views*. Fisher & Son, London, opp. p.35. This is looking east. Water is issuing from the adits halfway up the face on the right and powering three waterwheels and stamps. Movement of material is by wheelbarrow and by mule/horse, some of which can be seen in the centre. It is known that about this time a small steam engine was installed to power some of the stamps, it may have been housed in the building in the centre.

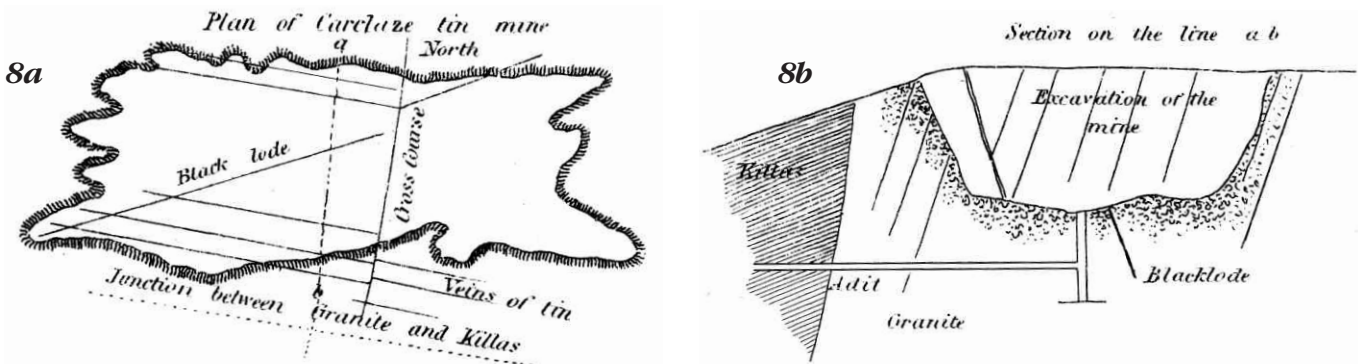


Figure 8. Plan (a) and section (b) of Carclaze from Von Oeynhausen and Von Dechen (1829). Although somewhat diagrammatic, the plan shows the effect of the cross-course lodes and the presence of a 'black lode' which appears to dip steeply northwards. Note that the granite margin is portrayed dipping much more steeply than in the Collins section (Figure 2). The canal level is not shown as the entrance was collapsed at the date of this plan.

a succession of parallel veins of schorl rock which... appear both in their range and dip to correspond exactly with the beds of killas in the immediate neighbourhood. This schorl rock seemed to pass into the slate by insensible gradations. This... induced me to believe the whole mass was stratified, but subsequent observations convinced me that this must have been erroneous' (Sedgwick, 1822).

In 1831 Sedgwick mentioned Carclaze in his Presidential address to the Geological Society. He says: "After examining this district with Professor Whewell during the summer of 1828, we left in the conviction that several of the neighbouring tin works [to Carclaze] were opened not upon true 'lodes', but upon 'veins of segregation' [of schorl-rock]". This is an intriguing comment as it foreshadows the present debate about

whether there was a sub-solidus immiscible borosilicate phase in the granite (Bristow, 2004), which formed the irregular masses of schorl-rock seen in many china clay pits.

A further paper published by Sedgwick in 1835 enlarges on these observations, and indulges in some fascinating speculations about the relationship between parallel veins in granite, slaty cleavage, bedding and stress, which were probably way ahead of his time. The visit to Carclaze and other locations in the St. Austell Granite by Sedgwick helped to bring the origin of veins and slaty cleavage into open debate.

The next figure of note to visit Carclaze was Sir Henry De la Beche. In the first publication in 1839 by what was to become the British Geological Survey on the geology of SW England, he mentions Carclaze several times, describing the way the tin

occurs along 'divisional planes' in the altered granite and in the adjacent 'schorlaceous' masses. He recognises that there are several sets of intersecting veins and also provides a sketch of the south face of Carclaze Old Pit (Figure 9, reproduced courtesy of the British Geological Survey), presumably drawn by his own hand.

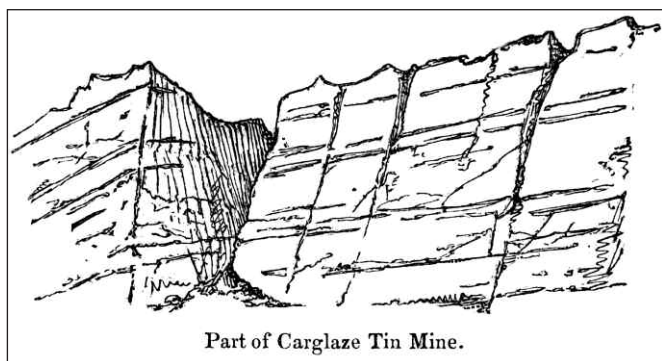


Figure 9. Sketch of the south face of 'Carclaze' pit from De la Beche (1839). The horizontal lines are probably greisen-bordered quartz-tourmaline veins. Reproduced courtesy of the British Geological Survey. IPR/106-73CT.

There are many later descriptions of Carclaze by authors such as Collins (1878) and Henwood (1843) but, as far as the geology is concerned, they mainly repeat the observations given in earlier descriptions. Stocker (1852) reported that the canal tunnel had been recently rediscovered and a tramway routed through it. A plan by Symons dated 1877, showed the old canal tunnel converted into a tramway; when it was re-opened he reported that sixteen or eighteen of the old canal barges chained together were found inside. However, by 1877 operations had moved north to Old Baal in order to exploit china clay and very little tin ore was being produced.

A painting by Elliot in 1892 shows that the old tin pit is now well and truly abandoned with sheep grazing on the vegetation in the bottom. The drainage adit would still have been functional; later a further adit, at a deeper level, was cut in about 1908 in order to facilitate china clay working in the two Baal pits. A photograph by the Geological Survey, taken in 1905 (Figure 10), shows that the face described by De la Beche and others is little changed. This face, possibly dating back to the time when Sir Henry De la Beche sketched it, is still there (Figure 3) and is a proposed RIGS site.



Figure 10. Photograph of the south face of Carclaze pit, taken in 1905 by the Geological Survey of Gt. Britain, note the comparison with figures 3 and 9. Reproduced courtesy of the British Geological Survey. IPR/106-73CT.

MINING TECHNOLOGY TRANSFER TO THE EARLY CHINA CLAY INDUSTRY

It is important to recognise the role that operations such as Carclaze Old Tin Pit and the Happy Union tin streaming operation in the Pentewan valley played in developing the mining technology which was later adopted by the early china clay industry. Jars (1781) describes how iron tools were used in Carclaze Old Pit to disintegrate the soft kaolinized granite in a stream of water running down the face and convert it into a slurry. As late as the early 20th Century a similar technique was used with men using 'dubbers' to break up the kaolinized granite in a stream of water cascading down the stope, in order to create a slurry of the constituents of the kaolinized granite suspended in water.

Jars also describes how a drainage adit under the bottom of Carclaze Old Pit was used to remove the slurry of clay and sand to an adjoining valley. Happy Union tin stream works in the Pentewan valley was also described by many early travellers and geologists. Diagrams in an anonymous (probably by Raspe) account of the Happy Union open pit, published in Berlin in 1790, based on a visit in 1783 (Figure 11), shows a waterwheel powered pump connected to the pit bottom by an adit. Drainage adits connected to nearby valleys were features of many of the earliest china clay pits. Later, as china clay pits became deeper than any nearby valley, waterwheels and beam engines were used to raise the slurry to the surface, or to a drainage adit. However, as late as the 1950s, the Carclaze group of pits still discharged its slurry through a drainage adit to the adjoining valley at Phernyssick, although at a much deeper level than in Jars time, to allow for the development of the Baal china clay pits to the north in depth. Lee Moor china clay pit, in the southwest corner of the Dartmoor Granite, discharged its slurry through an adit until recently. Since the Second World War most pits have used electrically driven pumps to pump the slurry up from the pit bottom through pipes laid on the side of the pit, thereby eliminating the need for drainage adits.

Jars also describes how gravitational settling in water of the coarser fraction of the slurry was also a feature of the Carclaze operation, before the commercial production of china clay had begun. Gravitational settling is still one of the main techniques used by the present day china clay industry for particle size separation.

The early china clay industry also made extensive use of waterwheels, usually for pumping, as can be seen at the present day at Wheal Martyn China Clay Museum near St Austell, although some early china clay operations also used waterwheels to power stamps which crushed any lode with a recoverable tin content encountered in the pit. The kind of arrangement at Happy Union (Figure 11) of a waterwheel driven pump connected to an adit under the pit bottom is similar to many early china clay operations.

Happy Union also had an incline with two counterbalanced skips running on rails which was used to raise the 'tin ground' (the lowest layer above the bedrock in Figure 11) from the pit bottom to the surface where clay and coarser material could be separated by a stream of water. This is reminiscent of the sand pits, skips and inclines, with their associated conical tips, used in nearly every later china clay pit to separate and dispose of sand. The Happy Union incline could have provided the blueprint for these.

There is little doubt that the rapid early growth of the china clay industry from 1800 onwards was greatly helped by the ready local availability of appropriate mining technology inherited from the open-pit tin mining industry, together with labour skilled in its operation.

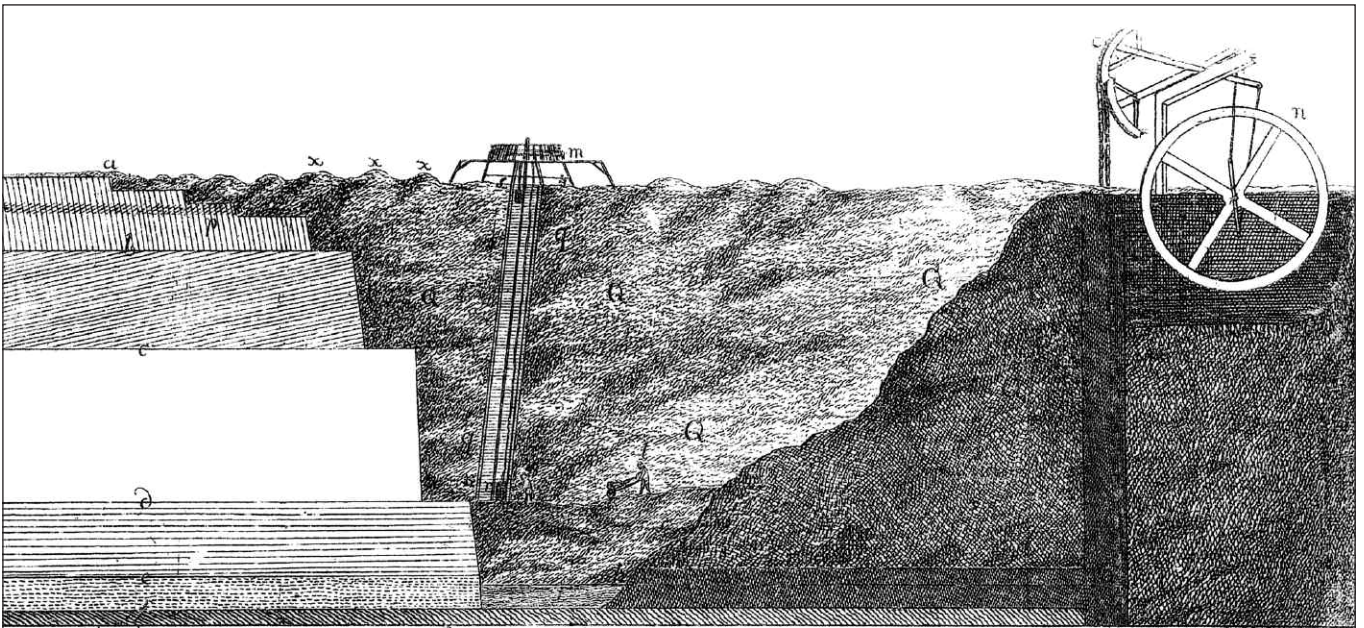


Figure 11. Happy Union tin stream works in the Pentewan valley. The Holocene sequence rests on the bedrock; the lowermost bed is the 'tin ground' which was the object of the excavation. In the background can be seen the incline with two counterbalanced skips used for removing the tin ground from the pit bottom, powered by a horse whim at the surface. The skip automatically discharged at the top into a stream of water, which washed away the clay, before further processing to recover the tin ore. Note the similarity to inclines and skips used in the 19th Century and later for sand removal from china clay pits, also note the waterwheel powered pump connecting via an adit to the pit bottom, just as in later china clay pits. Several workers with wheelbarrows can also be seen. From an anonymous paper, published in Berlin in 1790, based on a visit in the autumn of 1783. The author was probably Rudolf Erich Raspe, a well-known German intellectual and author of *Baron Munchausen's Travels*, from the principality of Hesse, where he was wanted for embezzlement, hence the anonymous authorship.

CONCLUSIONS

(1) Carclaze was one of the largest open pit tin stockworks being worked in SW England in the late 18th and early 19th centuries and it provided a uniquely informative location for early geologists to develop concepts concerned with the alteration of granites and metalliferous mineralization.

(2) The evidence from Carclaze indicates that the kind of practical economic geology which a present-day geologist working in the extractive industry would be familiar with, was evident in the late 18th and early 19th Century accounts of Carclaze by French and German scientists. It could be argued that the role that this kind of geology played in the inception of geology in this country has not been sufficiently recognised. However, Sedgwick's later role in 1822-35 is significant and is early evidence of academic interest in the formation of mineral deposits.

(3) The underground canal at Carclaze, possibly constructed as early as the first half of the 18th Century, is a strong candidate for the earliest underground canal in Britain.

(4) Much of the 19th Century open pit mining technology for china clay was inherited from the local open pit tin mining industry, which had developed it in the latter half of the 18th Century. This greatly aided the rapid growth of the early china clay industry.

(5) The success of the Carclaze open pit operation for tin was crucially dependent on the engineering of an elaborate water supply system which provided both the power and the process water.

(6) The unique historical associations with some of the founding fathers of geological science and the innovative mining engineering at Carclaze, mark it out as a significant part of the industrial heritage of Cornwall, representing pioneering developments at an early stage in the Industrial Revolution.

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