The early history of the Royal Geological Society of Cornwall 1814-1850

Thesis

How to cite:

For guidance on citations see FAQs.

© [not recorded]

Version: Version of Record

Copyright and Moral Rights for the articles on this site are retained by the individual authors and/or other copyright owners. For more information on Open Research Online’s data policy on reuse of materials please consult the policies page.
27. The entry, by Robert Hunt, refers to Carne (1822A). Hunt wrote of this paper: "The celebrated Werner was drawn by it into Cornwall, and he visited the mines in the County in company with Carne". As Werner died in 1817, and the paper was first read in 1818, and published in 1822, this visit seems to have been unlikely. There is no evidence in local newspapers, etc to suggest that Werner had visited Cornwall; and Ospovat, in the 'Introduction' to Werner (1971) states that Werner rarely travelled outside Germany (29-31).

28. Letter to Sir Christopher from John, (nd), Hawkins Family Papers, CRO J 2246C/14.


30. Hawkins (1818B), (242-3).

31. Ibid. (243).


33. Quarterly Meeting 10th November 1823, RGSC Minute Book No.1. The name "C Dufreni" was written in the Minute Book; P A Dufreynoy was a co-author with Elie de Beaumont of Voyages metallurgique en Angleterre (1827).

34. See various 'Librarian's Reports' in RGSC Annual Reports for details of publications received.

35. Carne (1827A), (49, 75-6).

36. Quarterly Meeting, RGSC Minute Book No.1. This entry was not dated, but by the position in the Minute Book it is possible to deduce that it must have been held in May 1814.

37. RGSC Annual Report 1815. A "Cap't John Davy" had been "unanimously elected an associate member" in July 1814, perhaps because of his reply to the list of questions. Monthly Meeting, 1st July 1814, RGSC Minute Book No.1.

38. RGSC, List of Members of the Society, 1815.


40. RGSC Minute Book No.1.

41. RGSC Minute Book No.1, and RGSC Annual Reports 1815-20.

42. Carne (1822A).

43. Ibid. (50-1).

44. Ibid. (68, 80).

45. Ibid. (51).
BEST COPY

AVAILABLE

Poor text in the original thesis.
Some text bound close to the spine.
Some images distorted
DENISE ANNE CROOK
BA, BSc (Econ)

THE EARLY HISTORY
OF THE ROYAL GEOLOGICAL SOCIETY OF CORNWALL:
1814-1850

Submitted for the Degree of Doctor of Philosophy
of the Department of History of Science and Technology,
Faculty of Arts,
The Open University

Authors number: C0103851
Date of submission: 12th September 1990
Date of award: 3rd December 1990

14th September 1990
In this and the two following sections, three case studies will be presented, contrasting some of the contributions to science and the arts made by the RGSC, and attempting to assess the extent to which the society was successful in carrying out certain of its objectives. These case studies will examine the attempts made to complete a geological map of Cornwall, the formulation of a theory about the genesis of mineral ores, and the promotion of instruments intended to save lives in mines.

Most geological societies of the early nineteenth century included among their objectives the completion of a geological map of their own area; the RGSC was no exception. In the Laws of the society, presented to the initial meeting on the 11th February 1814, a proposal was included to establish a Chart Committee, "the objective of which shall be to construct a series of charts, illustrative of the geology of the Cornish coasts". This proposal may have been included in imitation of a similar committee established by the Geological Society of London, which was in the process of preparing its own map of England under the leadership of G B Greenough. Other societies which intended the preparation of maps included the Natural History Society of Northumberland, the Manchester Geological Society and the Yorkshire Geological Society; their undertakings will be described below.

The interpretation of the geological structure of the areas that societies attempted to map will not be discussed, even
though there are significant differences between the maps produced in the early 19th century, and those of the present day. The real problems faced by scientific societies were how to interpret the geology of an area and achieve a satisfactory map with only very limited knowledge of the techniques required. Societies also experienced great difficulties in trying to involve amateurs in the construction of geological maps.

5.1 Geological maps, and the problems associated with their completion

Geological mapping was a comparatively new activity at the beginning of the 19th century, especially in England. However geologists in England would have been aware that some of the first maps purporting to show the mineralogy of an area had already been produced in Germany and France (e.g. *Atlas et description minéralogique de la France*, (1780)).

A geological map was expected to demonstrate that a society had achieved a scientific objective; the RGSC referred regularly to the progress of its map project in *Annual Reports*, realising that its completion was a matter of importance, both because of pride in the society's anticipated accomplishments, and because it had been stressed by the Council that it was a worthy project to support. Members perhaps hoped that such a map would receive more publicity than a paper published in a volume of *Transactions* because of its novelty, and because it was likely to be of use to landowners and mine adventurers. The map, once accomplished, could also be used for teaching
members about the geology of their own area, and as a field guide. A map was also thought to be capable of completion through co-operative efforts by members who had only the most basic knowledge of geology. The first "co-operative" map, that of the Geological Society of London, was still in preparation at the time when the RGSC formulated its own project, but because the two societies had some members in common, the Penzance society should have been well aware of its London counterpart's aims.²

The production of a map was also seen as an aspect of the promotion of useful knowledge. The utility of geological maps to landowners was beginning to be recognised. Agriculture could benefit, because the nature of soils is determined by the underlying rock, and this information would be made available through the medium of a map. Knowledge about sources of stone for building and road making would also be enhanced, and was important in an age of industrial expansion. For these uses, a map of the surface geology would have been sufficient, but such a simple form of presentation of geological information would not have been enough for mining exploration and development. Many of the new societies had been founded in areas where coal or metallic ores were mined, so there would have been expectations that the information acquired when researching for a map would also reveal new deposits of economic minerals. One particular aim of societies in the north of England was to locate new coal measures, fit for exploitation. In the south west, the main economic minerals of interest were tin and copper, although smaller deposits of silver, lead and iron were also workable. All these societies did intend that
their maps should show the mineral lodes or coal seams of their district.

The societies faced two problems when trying to map underground resources and structures. In the first place, it was necessary to devise a method of showing three dimensional geological structures on a plane surface; one way of overcoming this difficulty was to use vertical sections to complement a map. Sections and sketches are not a substitute for a map, although used together with a map they can amplify and extend the information available into the third dimension.

A more serious difficulty was that in order to locate mineral deposits, some knowledge of their origin and mode of deposition was necessary. For example, in the case of the tin and copper deposits of Cornwall, the relations between the lodes and the granite masses are relevant. Perhaps the greatest difficulty that the RGSC, and other societies, faced in the early years of the nineteenth century was to understand the necessity of mastering the theoretical knowledge required to complete a satisfactory map showing the geology of an area and its mineral resources. In the RGSC, work on the origin of mineral veins proceeded concurrently with the work on a map.

A satisfactory geological map also needs be based upon geological theory which explains the sequences of the strata shown; some early English maps were linked to ideas explanatory of the stratigraphy of the area covered, for example that of William Smith, published in 1815. The Geological
Society of London under the leadership of Greenough was however opposed to the theoretical approach, depending instead upon Baconian fact gathering, and this created additional difficulties for the production of its map. The RGSC was to face similar problems.

5.2 Early mineralogical and geological maps of Cornwall

The first geological map of Cornwall is said to be that of William Maton, drawn in 1796, and published in his *Observations... of the western counties of England* in 1797. This was a small map (two octavo pages showing the whole of south western England, including Devon, Dorset and Somerset), and was reproduced in black and white (see Figure 12). It showed only the surface geology, and made no attempt to indicate mineral resources. It should be noted that Paris had been recommended to his medical position in Cornwall by Maton, although there is no evidence that he and Maton ever discussed either geology or the production of a map. Neither William Borlase in *The Natural History of Cornwall*, nor William Pryce in *Mineralogia Cornubiensis*, had included mineralogical maps.

An obituary in the *West Briton* of 1840 of Benjamin Sampson, one of the first Associate Members of the RGSC, referred to a map and sections that he had prepared "about 40 or 45 years ago" of the North Downs mining area. Sampson's election to the society as an Associate Member was made in recognition of his presentation in January 1815 of some plans of another mine, Wheal Pever. None of these plans has been traced, so it is only possible to guess at what might have been included,
but the links with the mining industry are clear.

John Hawkins referred to a map which he had made for himself, in a paper given to the RGSC in 1818. As he left Cornwall in 1804, not returning until 1828, this map must have been made well before the foundation of the society. It has not been possible to find the map, but he gave a brief description of it in his paper, which suggests that its purpose was geological rather than mining: 9

In an attempt which I once made to express by colours on Martyn's map, the different strata of the county, I perceived that the granite hills formed several distinct and insulated groups of a circular form.

William Phillips of the Geological Society of London, and also a member of the RGSC, prepared a mineralogical map of Cornwall in the early part of the 19th century. 10 In a paper for the Transactions of the Geological Society of London in 1814, he wrote that he had prepared the map to see whether lodes traversed the whole county, and not for publication: "The map was preserved merely with a view to private gratification". 11 A small scale map of England and Wales, published in 1822 in the book which Phillips co-authored with Conybeare, was said by Phillips to have been compiled "chiefly from Mr Greenough's". 12 It is not known whether Phillips used his own knowledge of Cornwall when that part of the map was drawn. The book did not cover the older rocks, such as those of Cornwall, as it had been intended to publish a second volume, but this was never done.

In 1817 a proposal to prepare a map of the mining district of Redruth was made by Richard Thomas, a surveyor from Falmouth.
He wrote in the introduction to his Report, published in 1819: 13

When this survey was entered upon, there was no intention of laying before the public anything more than a plan of the surface, with the situations of the mines and their lodes, courses and adits, which are sufficient to make a very interesting Map; more particularly to those who have property within the district, as land-owners, bounders, mine-adventurers, &c. But when it was seen that so much additional valuable information could be obtained, the surveyor of course availed himself of such a favourable opportunity of extending the utility of the work...

The surveyor... waits the results of his present publication, before he extends his speculations, which are undertaken at his own risk and expense.

The survey included a map and sections showing some of the mines in the central mining district of Cornwall. The map was not a geological one, and it is clear from the quotation above that it was not intended to be. Thomas did however express a hope that it would be of assistance to geologists, who would be enabled to complete a fuller description of the district. 14 The map did show the lines of the junctions between the granite and "killas" (the clays and shales), and these were also shown on the sections, but there was no attempt to explain or interpret the differences between the two types of rock in terms of their origin or the location of mineral deposits.

The final paragraph of the quotation above implies that although Thomas had been obliged to fund this publication on his own, he anticipated that sponsorship might be forthcoming for similar ventures. It is also possible that he had hoped to find sponsors for this first mining survey. In November 1817, the Council of the RGSC had received a letter from him about his intentions, and at the Anniversary Meeting in October
1818, Davies Gilbert had stated that he thought that Thomas's map "deserved to be patronised". There is no evidence however that the RGSC assisted Thomas in any way, financial or otherwise.

Thomas made further attempts to obtain financial assistance for his survey work. In 1823, an advertisement was inserted in the *West Briton* stating that he intended to publish "in manuscript", a map of the northern mining district of Cornwall, so it seems probable that he had not made money from his first attempt at publishing a survey of mines. In 1829 he offered his work to the RGSC on condition that the society would publish the maps and allow him one half of the profits. The RGSC did not accept this offer; by that time the members had made alternative plans for their own map and survey of the Cornish mines (see below), and it is unlikely that they would have wished to compromise these efforts. A report of the society's Anniversary Meeting, in the *West Briton* for October 1828, referred to Thomas's offer:

> This proposal has been so recently made that the Council have not been able to pay any attention to it; but they recommend it to their successors to ascertain, in the first place, whether Mr Thomas's labours include everything which ought to be comprised in a geological map; and secondly whether it is likely that the sale would defray the expense of publication. The profit, if any, should wholly belong to the meritorious individual who had thus devoted his time and abilities to the completion of such a desirable object. But whatever may be the result of this proposal, it ought not to interfere, in the smallest degree, with the mode already proposed, of proceeding with the geological map of Cornwall.

In 1835, Thomas presented 1,400 specimens, which illustrated his map of the mining districts, to the RIC. He may have donated these specimens to the Truro society because his
offers had been rejected by the RGSC. He was not a member of the latter society at this time, although he did later become a corresponding member.\(^\text{20}\)

In addition to those maps specific to the south west described above, two geological maps which included Cornwall were published in this period. The first was that of William Smith, published in 1815; the second, by G B Greenough, was published in 1820.

5.3 The RGSC and a map of Cornwall

Progress in mapping in the RGSC was dependent on individual members and their interests and enthusiasm. The secretaries of the society were particularly important in directing the lines of research, and some were more motivated towards the projected map than others. Their ideas and those of some of the members about the importance of geological theory were also crucial in determining the type of map and progress towards its completion.

Exactly what type of map the RGSC initially intended to produce is unclear. The Laws referred to "charts illustrative of the Cornish coasts"; whether this referred to charts in the nautical sense, or to vertical sections of cliffs is uncertain. There were several naval officers among the early members, one of whom was to be appointed a member of the Chart Committee (see below). Rudwick suggests that geological sections were rare before about 1810, except for vertical sec-
tions of the underground workings of mines. 21 Mine sections were quite commonly used in Cornwall, and both Borlase and Pryce had included examples in their works. 22 Borlase had also included a sketch from the sea of Porthanvon Cove near St Just, which showed the raised beach. 23 Mine sections however had a different function from geological sections, and did not usually include any interpretation of the geology. The first English maps to be published together with true geological sections were those of William Smith (1815), and Webster's of the Isle of Wight (1816), 24 but neither of these been published by 1814, and so would not have been available to the members of the RGSC. It is possible that many of them had never seen a geological map, although they would have been more familiar with mine sections, as both Borlase's and Pryce's works had been sponsored by many of the gentry of Cornwall. 25 The library did however possess a copy of Fitton's Notes on the mineralogy of part of the vicinity of Dublin (1812), which included a map of the Dublin area. 26 On the other hand, neither Maton's book with his map of the south west, nor the work of Cuvier and Brongniart on the Paris basin (Carte géognostique (1811)) were in the library of the RGSC by 1818. 27

In March 1814 the members of the Chart Committee were recommended to the society. There were eight in all, including Paris, Majendie, and Captain Halliday (a naval officer). 28 There was no record of instructions made to the Committee, and this was the last reference to it in the minute books. In July 1814, however, a series of rock specimens from the coast of Mounts Bay was presented to the society by Majendie, and
"Drawings of some of the most interesting junctions were exhibited by Cap't Halliday". Halliday also prepared some "drawings of the cliffs and strata" of the Lizard in the summer of 1814, but these were not included with the map of that district, prepared by Majendie, and published in the first volume of the society's Transactions. None of these drawings have been found in the society's archives. In October 1815 a paper by the Rev Samuel Trist of Veryan was read, on the limestones of his parish. It was published in Transactions I, together with a geological section showing the location of the limestone, and a sketch map indicating the outcrops of the rock (see Figure 13).

In November 1815, a paper by Majendie on the Lizard District was read, "containing the results of an investigation into the boundaries and position of the serpentine formation". According to Paris it was compiled while Majendie "bivouacked" at the Lizard for a week. The paper was reproduced in Volume I of the Transactions, together with his map of the district. This was the first detailed geological map of this area, and of any part of Cornwall, that is still extant. (See Figure 13 for the area covered by this map.) The Rev Adam Sedgwick referred to his own examination of the rocks of the Lizard formation in a paper for the Cambridge Philosophical Society in 1822, and he described the boundaries between the serpentine and porphyry as "traced with considerable accuracy in Mr Majendie's map of the district". This map was however only a representation of the surface geology, and there was no interpretation of the geology of the area in Majendie's accom-
panying paper.

By November 1814, the society appeared to have altered its ideas about the proposed charts, for it was decided that a map of the mining districts was to be drawn up, and there were no further references to cliff sections. There was no indication in the society's records as to why this alteration in policy should have been made. It is possible that an imminent recession in mining (see Figure 2 (p.9) and Appendix 2) may have precipitated a change, and that mine adventurers decided to seek help from the society in locating fresh sources of ores; the Minutes of the Quarterly Meeting held in the autumn of 1814 included a list of donations from some of the gentry and mine adventurers towards the museum and "a geological Map of the Mining Districts of Cornwall". A total of 50 pounds was donated by the adventurers of three mines, Dolcoath, Cook's Kitchen and Wheal Fanny, all owned by Lord De Dunstanville. In all, £270 was given, but as no 'Treasurer's Report' was published until 1820, it is not possible to establish how much if any of this amount was spent on mapping. The Annual Report for 1820 stated that: "The details of the Expenditure, being too voluminous for this Report, may be inspected on application to the Treasurer"; however no Account Books of this period have been preserved. None of the 'Treasurer's Reports' in the years up to 1832 gave any details of expenditure on mapping activities.

William Smith's geological map of England and Wales was published in 1815, and in November of the same year, a copy was presented to the RGSC by Davies Gilbert (see Figure 14).
KEY TO FIGURE 14

**Figure 14a**
Detail showing the title of *A delineation of the strata of England and Wales*, by William Smith, 1815, presented to the Royal Geological Society of Cornwall by Davies Gilbert in 1815.

**Figure 14b**
Detail of the William Smith map of 1815, showing the southwest peninsula.

**Figure 14c**
Detail of Martyn's *Map of the county of Cornwall*, 1784, showing the colouring of part of the Hundred of Pydar, and the incomplete key.

Photographs by Mr Courtney Smale, current President of the Royal Geological Society of Cornwall.
Figure 14a

This donation provided an opportunity to see ideas about strata, coal, and minerals. The same year an 1815 map including the Cumberland and District Mines was released. Gilbert, who had correspondence with the Society, made use of the new maps and list of acquisitions by the Council of the Geological Survey. When the Geological Survey maps earlier in the 19th century were made, the society took advantage of assistance from the survey. As a result, the geological map of the country was made more accessible than this offer called for.

A DELINEATION of the STRATA of ENGLAND AND WALES, with the SCOTLAND, IRELAND AND MINES, the Marshes and Fen-lands, depressed by the Sea and the VARIETIES of SOIL, according to the observations in the superfete, illustrated by the most descriptive names.

By W. Smith
This donation must have given most members their first opportunity to see a geological map. Smith's map was based on his ideas about fossils and their use in ordering sedimentary formations, but in Cornwall in 1815, the rocks were believed to be unfossiliferous. There was therefore little theoretical assistance from this map for the Cornish one. Nor did the 1815 map include much information on mineral deposits. In the same year as Smith's map was published, the 'Report of the Council' of the RGSC suggested that information on mines and minerals was still important: 38

...a very considerable mass of material has been collected for the construction of a Geological Map of the county; the Miner also has been enlisted into our service and has presented much valuable information...

The Ordnance Survey sheets covering Cornwall had been published in 1813. These maps should have been of great assistance to the society, as the members would have had one inch to the mile topographical maps on which to record their geological investigations, something which many areas of the country still lacked. At the Anniversary Meeting in 1816 it was reported that Colonel Mudge (of the Ordnance Survey) had offered his assistance "in the completion and publication of the geological map of the County of Cornwall". 39 It is possible that this offer came through the offices of Davies Gilbert, who had corresponded with Colonel Mudge about the Survey maps earlier in the year. 40 There is no evidence that the society took advantage of the Colonel's offer, or indeed made any use of the new maps. There was no record of the purchase or donation of the sheets in the minutes, or in a list of acquisitions by the library appended to Volume I of
the Transactions. Majendie had had to use Martyn's Map of Cornwall (published in 1784) for his map of the Lizard.

The Annual Report for 1816 was very optimistic about the progress of the map (see Figure 15 for the Hundreds named in the following quotation):

The Council has seen with considerable satisfaction the considerable progress which has been made in the construction of a GEOLOGICAL MAP of the County; the interesting Hundreds of Penwith and Kerrier are already finished, the rocks which constitute their surface are distinguished by appropriate colours, and their successions, relative positions, and various junctions and transitions into each other are traced and delineated with an accuracy and detail that cannot fail to render the Map a most acceptable Tribute from Geology to Agriculture and the Arts;... The completion of this great desideratum may be confidently anticipated before the next Annual Meeting, but the Council begs to remind the Society that it will require the social and united exertions of its members, and they rely with confidence upon the cooperation of those Gentlemen who are more remotely resident.

This announcement is a puzzle; no map was ever demonstrated at a meeting and the minutes for this period were as complete as it has been possible to determine. The individuals who drew the map were not identified, nothing that correlated with the description appeared in any volume of the society's Transactions, and nothing has been found in the archives. One possible explanation may be found in a statement in the Annual Report for 1820:

...the Council think it right to state that the Geological Map of the County somewhat prematurely announced by the Society, in an early stage of its labours, under an incorrect impression of the difficulties of the task, need not be immediately expected, as it is the intention of the Council to defer its publication until a more perfect series of observations has been recorded.

If this report is compared with the previous one, it seems possible that the partial map announced in 1816 may have been seen by someone who criticised it so strongly that it was withdrawn, but there is no evidence that this happened. How-
ever in 1817, the Council's report had been much less optimistic, saying that the "unfavourable state of the weather during the previous year" had retarded progress on the map.45

Paris left Cornwall in the autumn of 1817, but he remained responsible for editing the first volume of Transactions. He wrote rather optimistically in the Preface to Volume I:46

In the construction of a geological map of Cornwall, the Society has made considerable progress, and the Council trust that from the zealous and united exertion of its members, its completion may be confidently anticipated.

In September 1817, Paris's place as secretary was taken by John Forbes, and in June 1818, Forbes gave the first of a series of four papers on the geology of West Cornwall. Although the texts of his four papers were not included in the Minute Book, it is possible to deduce from their titles that some of them, if not all, were combined to form the paper in Volume II of the Transactions 'On the geology of the Land's-end district'.47 This paper was described as having been read in September 1819, the date of the last of the four papers.

Volume II (1822) of the society's Transactions included a map of the surface geology of West Cornwall, from the Hayle Estuary westwards, with a scale of 2 miles to the inch, and a section of the cliff at Gurnards Head (see Figure 13 (p.141)).48 Forbes referred to the map and plate in his text, but did not say whether he drew them, nor did he attribute them to anyone else. In the Annual Report for 1818, a list of donations had included a "valuable map, plans and drawings of the Geology of Western Cornwall" presented by Richard Moyle.
Whether these were the ones included in the *Transactions* is unclear. The only name on the plates in the volume was that of the draftsman, John P Vibert.

Forbes included nothing in his paper on the mineral deposits of the area, but this was a deliberate omission, as a paper by Joseph Carne read in October 1821, and also published in Volume II of the *Transactions*, covered the 'Mineral productions of the Parish of St Just'.

A map attached to the paper showed the mineral lodes in very great detail, and also the location of every mine and stream works, working or abandoned, that Carne had been able to discover (see Figure 13). It also showed the coastal locations of collectors' minerals. This was the first attempt by the RGSC to include information about economic resources on a map. Neither this map, nor that accompanying Forbes's paper, show evidence that any geological theory about the formation of granite, etc, was used in their compilation. Carne did however note in his paper that the junction of the granite and slate "greatly affects both the tin and copper lodes", and he suggested that tin lodes were richest when they lay immediately between the two rocks, but he made no attempt to explain this phenomenon.

Forbes, in his paper on western Cornwall, explained that he could accept neither the theory of Werner, not that of Hutton, as correct interpretations of the formation of the granite and slates in this part of Cornwall. His conclusion echoed the Baconian ideas of G B Greenough:

I ought perhaps to apologise for the total absence of any of those ingenious speculations or theories which, to some, may seem the very essence of geological discussions. I must, however, observe that theoretical subjects did not at all enter into my plan; and I humbly conceive, that I better
consult the interests of the society by adding one new observation to its stock of facts, or one new specimen to its cabinet, than if I wasted my time and theirs, in the construction and exposition of theories, which would probably prove useless, and might possibly be ridiculous.

At the same time as Forbes and Carne were at work on their own projects, efforts were also being made to involve more members in the compilation of the map, using the co-operative methods already tried by the Geological Society of London. In the 'Report of the Council', given at the Anniversary Meeting in 1818, reference was made to the "still very defective map", and members were asked to collect information and specimens from their own areas, which they were requested to send to the secretary. The Council's 'Report' continued:

Any person, although unacquainted with the principles of Geological Science, can, it is obvious, collect specimens of the various rocks in his vicinity, with the assurance that collections of this kind, with the various localities of the specimens affix'd will very materially promote the important object in view. One grand desideratum and which might be very easily supplied by members resident in different parts of the County — is, to ascertain the exact limits of the different Granite and Killas districts. The farmers and miners in any part of Cornwall could give this information to any gentleman that would take the trouble to record it, or to trace the boundary lines on any part of the County map.

This exhortation to members was repeated in identical terms in the Annual Report for 1819.

Mapping of a district is not however as straightforward as the Report suggested. G L Davies argues that early 19th century geology was a "simple science" to which all could contribute, but this cannot have been true of geological maps, other than those of the simplest type. It is likely that some members were not capable of reading any kind of map other than the pictorial ones often produced in the previous century,
because of their unfamiliarity with this form of representation. There is no evidence that any simple instructions were given to members, although in 1822 a paper by R W Fox 'On a proposed new method of drawing mining maps and sections' was read to the society; unfortunately the only remaining record is the title.

The Preface to Volume II of the Transactions explained that a geological map of the entire county should have been included, but that the society now wished:

...to shew not only the varieties of rocks, but also the locality and position of the principal metalliferous veins and the cross courses which intersect them, as far as they can be ascertained. This work, so interesting to the geologist and to the miner, had already occupied much of the time and attention of some Members; but it is an undertaking of immense extent and labour;...

As the society had already made a decision in 1814 to compile a map showing the mineral lodes, it is not clear why this explanation should have been necessary. It is however an indication of the difficulty faced by the society of defining precisely what should be shown on a geological map.

John Forbes left Cornwall in the spring of 1822 for a practice in Chichester. The new secretary to the RGSC was Dr H S Boase, who had been educated at the Cork Institution under Edmund Davy, and at Edinburgh. He continued to hold the post of secretary until 1827. From 1822 to 1826 there were no references to the map project in the very incomplete minute book, nor in Annual Reports. The third Volume of Transactions, published in 1827, contained no geological maps, nor any references to the project; there was however one geolog-
ical section, accompanying a paper by Dr Boase, 'On the sand-banks of the northern shores of Mount's-Bay'.

The Annual Report for 1827, written shortly before Boase's resignation, revived the subject again. The Council recommended that lithographic copies of "the various portions of the Map of the County on an enlarged scale" be distributed to members, for them to mark in the geology. This statement implies that Ordnance maps were not made available. A report in the Royal Cornwall Gazette for 1828, about the Anniversary Meeting of the society, stated that the lithographic copies had been found to be too expensive, and therefore an alternative plan had been devised:

A zealous member of the Society, George S Borlase, Esq. has, however, taken the trouble to divide the county into districts, which he has mapped on a large scale. The maps of the different divisions are now ready to be delivered to any gentleman who will undertake to mark on them the boundaries of the different rocks at the surface, and also the direction of the principal metalliferous and cross veins....

In February 1829 advertisements by the RGSC appeared in the Cornish weekly newspapers, informing members that the map sheets "as recommended in the Report of the Council at the last anniversary meeting" were now ready for collection from the secretary. The advertisement also listed areas which had already been allocated to "some friends."

The Annual Report for 1829 stated that several gentlemen "have kindly undertaken to lay down the geology &c, of the different districts" on the maps, and named some of them: "W M Tweedy, Esq., Mr Henwood, Mr Petherick, Lanescot Mine, G B Kingdon Esq. of Stratton, and Mr Mitchell of Breage." Thereafter
there was no further mention of this effort. Edward Giddy (secretary of the RGSC from 1827-1833) died in 1833, and George Borlase in 1837 after a long illness, so it is possible that the project was never followed through. In the society's archives there is a copy of the 1784 edition of Martyn's Map of Cornwall, part of which was coloured to show the geology (see Figure 14 (p.144)). The colouring was incomplete, for it included only the eastern areas of the county, although some mineral veins in the west were drawn in. There was an incomplete key with coloured boxes but no legend. There were no names added to the map, nor a date, so it is not possible to discover when the geological information was added, but it may have been an attempt to present the information gathered as a result of the efforts described above.

In 1830 the RGSC turned its attention to a project begun by its former secretary, H S Boase. Whether there was any connection between this effort and the proposals for co-operative efforts made the previous year is not clear. The Annual Report for 1830 said that: (See Figure 15 (p.147) for the areas named in the quotation.)

...their late highly respected secretary, Dr Boase, has during the past summer investigated the geological structure of the North, and a considerable part of the centre of this county; he has traced the rock formations of Pydar, Trigg, Lesneweth, Stratton and Powder... He has presented the Society... with a Memoir containing the results of these researches... This valuable contribution will not only form a very prominent feature in the Geology of Cornwall, but if followed up, would soon accomplish the Map, which has been so long in contemplation.

In 1832 the fourth Volume of the RGSC Transactions was published. A large portion of this volume was taken up by a paper by Boase in explanation of his map of Cornwall, also
included in the volume. 67 This was a map of the surface geology on a scale of four miles to the inch, and was accompanied by several sections. The cost to the society of having this map engraved was £20. 68 In the introduction to his paper Boase said that he "had devoted the past two years almost entirely to this object". 69 (Figure 16 shows the areas traversed by Boase in his travels, when researching for the map.)

Although the society had achieved a part of its objective with this publication, the map was not well received, and met with considerable criticism, especially outside Cornwall. Boase's interpretation of the geology of Cornwall was highly individual; he adhered to neptunian interpretations of the origin of primary rocks, but went further than Werner, writing that: "..all the primary rocks of Cornwall, even including the granite, are of similar composition, and probably of contemporaneous origin...I cannot refrain from stating my dissent from the doctrine of the igneous origin of granite". 70 According to Werner's classification, granite was an older formation than the greywacke and clay slates. Boase ignored almost totally the structure of the areas which he examined, devoting attention instead to the mineralogy of the rocks which he collected as he travelled around the county. The only description that he gave of the complex folding of the sedimentary rocks in the area around Bude and Morwenstow read: 71

Here the cliffs are very interesting, exhibiting a fine example of the curvatures and contortions of rocks; and the strata are heaped on each other apparently in utter confusion, dipping towards every point of the compass, and at various degrees of inclination.
KEY TO FIGURE 16

Traverses made by Dr H S Boase, 1830-31, for his geological map of Cornwall

1. Rough Tor to Crackington, via Davidstow
2. Rough Tor to Crackington, via Tintagel
3. St Breward to Pentire, via St Endellion
4. Blisland to Wadebridge
5. Wadebridge to Polruan, via St Neot
6. Polruan to East Looe
7. East Looe to St Cleer
8. Caradon Hill to Rame Head
9. Tor Point to Callington
10. Brown Willy to Launceston
11. Brown Willy to Widemouth bay
12. Morwenstow to Brown Willy
13. Hensbarrow to Bodmin
14. St Dennis to Tresillean
15. Padstow to Newquay
16. Borgotha to Tresillian
17. St Stephen to St Anthony, via Veryan
18. Veryan to Mevagissey, via the Dodman
19. Grampound to St Austell, via Charlestown
20. Carn Grey to Fowey
21. St Blazey to Lostwithiel
22. Redruth to Gwithian, via St Agnes and Chacewater
23. Gwithian to Penryn, via Camborne and Stithians
24. Mabe to Constantine
25. Wendron to the Lizard, via Helston
26. The Lizard to Looe Pool
27. Hayle to Helston, via Tregonning Hill
28. Helston to Cuddan Point
29. Falmouth to Mawnan

(The routes have been taken from H S Boase 'Contributions towards a knowledge of the geology of Cornwall' Transactions, Royal Geological Soc., Cornwall, IV, 1832, pp.166-474. (The spellings of place names are the modern versions.)
Boase was also extremely reluctant to accept the existence of fossil remains in Cornwall, and in the text he twice referred to the Tintagel fossils identified by J J Conybeare, disputing their existence. He wrote, "I cannot accept that the diverging striae, in the slate of Tintagel, are attributable to the impression of shells." Only at the end of his paper, in a postscript, did Boase say that he was prepared to revise his opinions on the fossils: "It is my intention to revisit Tintagel, and I will endeavour to obtain more satisfactory information on this interesting subject."

Boase purposely ignored the economic minerals of the county because "Mr Henwood, who is engaged in a survey of the lodes of Cornwall and Devon, will personally obtain that information" (see Section 6.6 below). He did however argue briefly that the mineral veins were contemporary with the rocks in which they had been formed.

Perhaps the most contentious parts of Boase's account were a new nomenclature which he devised to describe the clays and shales, and his insistence that all the major Cornish rocks, including the granite, were stratified. When he presented the first part of his paper at the Anniversary Meeting of the RGSC in October 1830, he was challenged by John Hawkins, who was present at an RGSC meeting for the first and only time. Hawkins had been to Freiberg, where he had been taught by Werner himself, and he had become a proponent of Wernerian ideas, so his argument with Boase was less likely to have been on the grounds of theory. What Hawkins did challenge were the field observations. Although he had not lived in Cornwall
for nearly thirty years, in his youth he had made an extensive study of the Cornish rocks, and felt that he could argue from firm principles. No detailed record of his criticisms at the meeting remains, but Hawkins wrote to Gideon Mantell:

I believe this man was a few years ago, profoundly ignorant of the science upon which he has now written a Treatise so pedantic and dogmatical. ...I perceive that his facts are arranged in a way peculiar to himself, and that he relieves his readers from the trouble of accounting for them. But what most excites my surprize is the new nomenclature which he has given us!

...I recollect however when I heard a part of this huge memoir read, that Dr Boase made some unaccountable mistakes in regard to the disposition of the slate formation in that part of the county which I had examined and I thought it but fair and candid to apprise him of it. I feel therefore no great confidence as respects this important circumstance, when he treats of the rest of the county.

Hawkins had another grudge against Boase, so his criticisms may have been biased. Hawkins had been a regular contributor of papers to the RGSC since 1817, and he had come to expect that all his work would be published and given prominence in the society's Transactions. Boase was the editor of Volume IV in which his own long paper appeared. In order to make room for this, two of Hawkins' papers were omitted, although it is not certain whether this was by accident or design. Hawkins took offence, writing on the back of a letter from Joseph Carne which had attempted to make amends for the slight:

It appears from the account of this transaction which is given by Mr Joseph Carne that Dr Boase after assuming the office of Editor of the Volume went on progressively adding to his first communication as fresh materials were collected, without regard to the bulk of his memoir or to the rights and pretensions of the other contributing members. The rule of priority therefore must have been violated by the position which his paper occupies as well as the rule of proportion by the bulk which he has assigned to it. Quare. Is their [sic] no control over these matters or is each member permitted to regulate the publication as best suits his fancy or his interest?
One consequence of this affair was that Hawkins never again submitted a paper to the society. Boase's work also met with considerable criticism nationally. He was one member of a delegation from the RGSC at the Cambridge meeting in 1833 of the British Association for the Advancement of Science. In the Geology Section, in the discussion following John Taylor's report on mineral veins, Boase found that his ideas on primary rocks were strongly attacked by Sedgwick, Buckland, Whewell and John Phillips on the grounds that he had no understanding of the concept of stratification. Vernon Harcourt also wrote to his wife:

Tonight the geologists in their turn are to have a field day and I suppose we shall turn out a provincial dissenter from the orthodox doctrines of the science, Dr Boase, and hunt him down for the amusement of the ladies.

Henry Boase must have felt that he had not had the opportunity to make his case in full, for he requested that the subject be brought up again at the next meeting of the BAAS, at Edinburgh in 1834. Meanwhile he published another work, *A treatise on primary geology* (1834), although this time he did not use the medium of the RGSC *Transactions*. At Edinburgh he found that his work was again attacked unmercifully by some of the more eminent members of the Geological Society of London, including Sedgwick and Lyell. It was argued that his observations were faulty and that he had failed to distinguish between stratification and slaty cleavage.

Boase's sole supporter seems to have been Robert Jameson, the editor of the *Edinburgh New Philosophical Journal*, and one of
the few remaining followers of Wernerian views in Britain. Boase had studied for his MD at Edinburgh, and may have been taught there by Jameson. In a review of *Primary geology*, Jameson wrote in his *Journal*: 87

This interesting work... ought to be in the hands of every geologist. Although some of the positions of the author have been contested, we are of opinion, that much of the reasoning, and many of the curious and important statements of Dr Boase, remain unaffected by anything that was said in the British Association at Edinburgh, or has been written on the subject of primitive geology.

The generally adverse reception of Boase's paper, map and book was bound to reflect badly on the RGSC. He was a representative of the society, as its secretary (he had been re-appointed in 1833, when E C Giddy resigned because of ill-health), and as a delegate to the BAAS meetings; his paper and map in Volume IV of the *Transactions* had been published with the tacit approval of the Council. The only comment still extant made by a member of the society was by Davies Gilbert at the Anniversary Meeting in 1833; he observed that the paper had attracted "considerable attention", and that it was to "take precedence of every other subject in the Geological Section" at Edinburgh in 1834. 88 The *Annual Report* for 1833 included the following cautious reference: 89

> [it] adduces many facts at variance with the prevailing theories, and advances some peculiar notions which have given rise to much discussion, and awakened a novel interest in Primary Geology.

There were no comments thereafter on the work in the minutes or Reports of the society. In 1834 however, Boase was presented with a piece of plate "for his long and valuable services". 90 The inscription on the plate included the following
words, which suggest that his work on the map was a major reason for the presentation: 91

Presented...as a testimonial of their approbation of his zealous exertions in promoting the objects of the Institution, especially by a laborious Survey of the County which has enriched the Museum with an extensive series of rare specimens, and the Transactions with a valuable Memorial and Map illustrative of the Structure of Cornwall. 1834.

In 1837 Boase again resigned his post of secretary, and moved to London. 92

In 1835 De la Beche had begun his geological survey of Cornwall. This was initially greeted with approval by the RGSC, for the Council said it would "venture to express a hope that every Member, if required, would cheerfully render any assistance in his power to facilitate this important undertaking". 93 Once the survey with its official government sponsorship had begun, the society had no further reason to support research for its own map; but it still had the survey of mines being carried out by Henwood to look forward to, and to promote the honour of the institution (see Section 6.6). A comment about De La Beche's survey, in the RGSC Annual Report for 1838, which hinted that it would not cover the mineral resources of the county adequately, suggests that the society may have felt that it was necessary to emphasise the importance of Henwood's underground survey. This part of the Report may however have been written by Henwood himself, in his capacity as secretary of the society, so he may have been attempting to draw attention to his own work: 94

The map (of what may perhaps not improperly be termed the surface Geology) of Cornwall, executed by Mr De la Beche, and the illustrative Memoir by which it is to be accompanied, - anticipated in the last Report, - have not yet appeared.
There is no evidence that De la Beche made any official contact with the RGSC for assistance in his survey; he did however visit the society in 1836 at the Anniversary Meeting, where he displayed those parts of his map which were already complete. He also received hospitality and help from individual members, of whom the most important was R W Fox. Others from whom he received assistance included Canon Rogers of Exeter (and Rector of Mawnan), and Henwood. De la Beche also listed most of the papers published in the RGSC's Transactions in the introduction to his Report on the geology of south west England, and made frequent references to them.

The long period of twenty years, over which the RGSC attempted to achieve the publication of a geological map, shows clearly the problems that a society with an amateur membership had to face. The amount of geological knowledge which could be acquired by listening to papers once or twice a year was insufficient to impart the detailed requirements that mapping involved. It is easy enough for an amateur to collect specimens, but unless information such as dip and strike (for sedimentary rocks) is also supplied, the rock by itself is only a partial record. Only in 1833 after the publication of Boase's map, was an attempt made to introduce "elementary essays", instruction in simple geology, at revived Quarterly Meetings, but these were not successful, for in 1836 it was reported that these had been discontinued "in consequence of the uniform non-attendance of the Members".

It is not always easy to locate the boundary lines between
granite and the killas (the shales and slates of Cornwall). In many parts of the county the junctions are well covered by cultivated soils, or by vegetation. The junctions are also obscured by the effects of regional metamorphism, a concept which was not well understood at the beginning of the nineteenth century. Only at the coasts in cliff sections, and in mines, are rock faces well exposed, and these are not always easily accessible. It is clear from the descriptions in Forbes's paper in Volume II of the *Transactions* that he had based much of his work on the geology of West Cornwall on cliff sections. He wrote: 100

...the coast is particularly favourable to the geologist, laying open to him, in every direction, by the most splendid natural sections, the exact structure and relations of the rocks of which the country is composed...

The RGSC never seems to have organised expeditions to study geology in the field in its early years. No information about such activities was recorded in the Minute Books or in the *Annual Reports*. There was only one newspaper report of a field trip, held in 1836 on the day after the Anniversary Meeting, an event which had been attended by a number of the country's principal geologists, including De la Beche and the Rev William Buckland. The report suggests that the expedition was made for reasons of entertainment, as well as the geology, and had been arranged with the visiting geologists in mind: 101

At the conclusion of the meeting the President informed the company that on the morrow (Saturday) morning, vehicles would be provided to convey such of them as were disposed, to some of the most interesting geological phenomena of the neighbourhood. Accordingly, about 20 or 30 ladies and gentlemen visited Polmear Cove, in Zennor, where all were delighted, not only with the practical lectures on geology from the "Savans", but with the wild romantic scenery of our
northern cliffs. At the end of the day's work, a collation including, squab, fish and parsley pies, and other specimens of our provincial peculiarities in the culinary art, were set forth on the rocks, and partaken of with all the relish which exercise, and the bracing "ocean air" could impart.

Field work is today seen as an essential part of many geological investigations, but this was not apparently true of the RGSC at the beginning of the 19th century. It is possible that it was thought that sufficient information could be imparted through the examination of the specimens which were exhibited at meetings and in the museum. As petrology appears to have been more important to the society than stratigraphy (see Section 8), the necessity of examining the field relations of rocks may not have been perceived. Meetings were regarded by many members mainly as social events, rather than opportunities for serious study, and rare or beautiful specimens of minerals could provoke interest, but not necessarily much genuine curiosity about their origins. It was not true that members would have been unwilling to take part in field trips, for many gentlemen made excursions into mines, and to see cliff exposures etc, and their experiences were described in RGSC papers and in travellers' accounts of the county.102

The only members likely to have had knowledge of the surveying techniques necessary for a map were those who had learned these skills in the mines, and they were the men who were least likely to join the society (see Sections 2.3.3 and 2.3.4 above). An amateur membership also had the disadvantage that few members would have had sufficient time to spare from their other pursuits to undertake lengthy investigations. H S
Boase had reported that he spent almost two years on the research for his map of Cornwall (see above). Very few of the members of the RGSC actively participated in the work of the society, and it would have been inevitable that the main burden would fall on the few who were prepared to take more positive steps. A change in the composition of the membership of the RGSC over the years, so that there were fewer men with practical knowledge of mining, and more gentry and passive spectators, reduced the pool of available skills (see Figure 17, and Tables 2 (p.53), 3 (p.58) and 4 (below)). By contrast, the first two Directors of the Geological Survey, De la Beche and Murchison, had each received training in military surveying at the Royal Military College at Marlow.103

It is possible also that mine owners would have been reluctant to let their agents disclose information about lodes and other mineral deposits, as these would have been valuable commercial secrets. However De la Beche found that he got full cooperation from Mines' Captains, at least when tracing the surface occurrence of lodes and in finding geological information. In his Report, he wrote:104

...we are anxious to take this opportunity of acknowledging the very able and kind assistance [the mines' Captains] have at all times, without one single exception, afforded us in tracing out the lodes on the surface, for the purpose of entering them on the Ordnance geological maps. We have to thank them, also, for the prompt manner in which they have answered all questions which bore upon facts connected with the geological phenomena exhibited in the mines under their superintendence.

There is other evidence that commercial secrecy was not a reason for refusing access to information about mines which will be discussed in the Conclusion.
<table>
<thead>
<tr>
<th>OCCUPATION</th>
<th>NUMBER</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gentry</td>
<td>35</td>
<td>37</td>
</tr>
<tr>
<td>Businessmen</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>Clergymen (C of E)</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Attorneys</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Medical men</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Mining professionals</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Naval Officers</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Unknown</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>94</strong></td>
<td><strong>99</strong></td>
</tr>
</tbody>
</table>

Honorary members: 31

Associate members: 17
KEY TO FIGURE 17

A - Business men
B - Gentlemen
C - Attorneys
D - Clergymen (Church of England)
E - Medical men
F - Naval Officers
G - Mining professionals
H - Miscellaneous
J - Occupation unknown

(See Tables 2a, 2b, 3, 4 and 8 for the statistics on which the pie charts have been based, and for explanations of the occupational categories.)
FIGURE 17
CHANGES IN THE
COMPOSITION OF THE
ORDINARY MEMBERSHIP
OF THE RGSC (see key)
The RGSC also failed to develop a stratigraphic theory on which the map could be based. Only after it became clear that the granites had been emplaced at a later date than the sediments surrounding them could the folding and alterations to the sediments, caused by heat within the granite, be identified and explained. In order for this to be possible, that part of the hypothesis of James Hutton, which dealt with the actions of heat within the interior of the earth, had to be accepted as a valid theory of the formation of the plutonic rocks. At least part of the reason why Boase was able to complete his map, however unsatisfactory, was that he did use theory, and could therefore mould his observations to fit it. (See also Section 6 which discusses the progress of work on the origin of the Cornish metallic lodes).

5.4 The geological maps of some other societies

Other societies faced problems similar to those of the RGSC in trying to achieve the completion of satisfactory geological maps. The Geological Society of London, like the RGSC, wanted its members to contribute facts and specimens, so that a map could be compiled through their co-operative efforts. In practice their observations were of very little use, being too localised. Like the RGSC, the London society failed to involve the "practical men" who could have been of most assistance. The Geological Society did eventually achieve publication of a map, but this was almost entirely due to the efforts of Greenough, and to complete it he had had to plagiarise parts of William Smith's map.
The Rev William Turner, when addressing the prospective members of the Lit and Phil in Newcastle in 1793, listed some of the objectives which he hoped that the members could accomplish. Among these he included "the position in which [coal] is found in the earth, the thickness and inclination of its strata". He also suggested that new "mineral treasures" and sources of mineral water might be located. The society intimated that it would be happy to receive information about coal or lead, including "specimens, draughts, plans, sections". None of these early resolutions included specific mention of a map to be accomplished by members, but in the last decade of the eighteenth century, the concept of mapping geological formations and mineral resources was not as widely understood as it would be twenty years later when the RGSC formulated its own proposals. There had been little progress towards such ventures in England at the end of the 18th century.

William Turner was also the main instigator of the plans for the Natural History Society of Northumberland, more than thirty years later. When addressing the members of this new society in 1829, he made specific references to a map, saying that "a geological map of his district is almost as essential to the country gentleman, as the topographical plan of his estates". This statement suggests that he would have been aware of the agricultural as well as mining uses of a map. By 1829, geological maps had become an accepted part of the new science of geology, after the publications by William Smith and the Geological Society of London.
The Natural History Society experienced problems very like those of the RGSC in trying to achieve its objective. The society tried to obtain the support of the mining industry, seeking both finance and information. In November 1829 a subcommittee was formed for this purpose, and the sum of seventy-four pounds was rapidly raised from the industry.112 The subcommittee reported in 1831 on the proposed map; it was to be "upon such a scale as that the out-crop of each principal bed of coal, sandstone, or limestone, shall be minutely laid down... and this to be accompanied with various sections through the strata to the greatest depth ascertained by the several mines now in course of working".113

Like the RGSC, the Natural History Society had to resort to seeking excuses for the delays in producing the promised map, citing in 1833 its preoccupation with the building of a museum.114 A similar excuse was made in 1834, although the Committee could also report that John Buddle, a "colliery viewer", had donated all his maps, plans and sections to the society.115 The Report for 1835 used the same excuses as before; the map was not mentioned in 1836-7.116

The Natural History Society of Northumberland published only two volumes of Transactions in its early years, Volume I covering 1830-31, and Volume II, 1832-8. The first volume contained 28 papers, of which four were concerned with descriptions of coal fields. Two were by John Buddle; the first, 'Synopsis of the several seams of coal in the Newcastle district', included a plate with a small scale topographic map;
the second included sections of some of the strata in the Newcastle coalfield. The same volume contained a plate, 'Sketch... on the geology of Northumberland', on a scale of 6 miles to the inch; no coal seams or other mineral deposits were marked. None of these efforts could be described as having accomplished the objective of a geological map of the area complete with information about coal and lead deposits. They were similar in kind to the maps published in the first two volumes of the RGSC *Transactions*. The second volume of the Natural History Society's *Transactions* contained no maps, although there was a paper by Thomas Sopwith 'On the application of isometric projection to geological plans and sections'. John Buddle, who seems to have been one of the more active members in this connection, died in 1842, and enthusiasm for a map apparently declined. Morrell suggests that part of the failure to achieve this objective must be attributed to the mine owners who did not want details of their coalfields made public.

The Natural History Society, like the RGSC, appears not to have organised field expeditions to study rocks in their setting, in its formative years. It was not until after the formation of naturalists' clubs that open air activities began to be really popular. The first such institution was the Berwickshire Naturalists' Club (1831); the Tyneside Naturalists' Field Club, which grew out of the Natural History Society of Northumberland, was formed in 1846, and soon became stronger than its parent institution, often joining with it to produce reports which emphasised the practical nature of their combined efforts.
The Yorkshire Geological Society, modelled on the Natural History Society of Northumberland, also failed to produce a satisfactory map in its early years. With an initial membership consisting mainly of coal mine owners, the necessities of commercial secrecy may have inhibited the free use of information for a map. In 1838, the secretary Thomas Wilson sought the advice of John Phillips about a museum for the society. Wilson had suggested that it should be restricted to "coalfield fossils and materials for a geological map of the coalfield". The society also joined in a co-operative project with the Manchester Geological Society, to complete a section across the Pennines, linking the Lancashire and Yorkshire coalfields; although this was nearly complete by 1843, it was never published.

All these examples show the very great difficulties that provincial societies faced in achieving their aim of a geological map. Only the Geological Society of London was able to achieve a satisfactory result, and its map is open to criticism (see above). For the reasons stated above, the map published by the RGSC under the authorship of H S Boase cannot be described as fulfilling the objectives of the society. The reasons for the difficulties experienced by the scientific societies can be summarised as, the inability of amateurs to understand and co-operate in a complex exercise, the failure by the societies to arrange practical instruction in field work, and the reluctance of industry to assist. It remained for a body of professional men, the Geological Survey under De
la Beche, to reach the necessary standards of competence.

NOTES AND REFERENCES

1. **Laws of the Cornwall Geological Society 1814.**

2. H B Woodward (1907), (30).


4. Laudan (1977), (530).

5. Maton (1797).


7. **West Briton 13th November 1840.** This plan (of North Downs) is unlikely to have been the same as that published in Pryce (1778), (Plate VII), for Sampson was born only in 1771.

8. Monthly Meeting, 4th January 1815, RGSC Minute Book No.1. The plans of Wheal Pever were listed among the donations to the Library in Transactions, Royal Geological Soc., Cornwall, I, 1818, (267).

9. Hawkins (1822C), (158).


13. Thomas (1819), (7,8).

14. Thomas (1819), (8).

15. Monthly Meeting 7th November 1817, and Anniversary Meeting 6th October 1818, RGSC Minute Book No.1.

16. **West Briton 4th April 1823.** Thomas had already published a chart of the Severn.

17. **West Briton, 17th October 1829.**

18. Ibid.


20. Corresponding Members were first elected in 1835. Thomas's name appeared for the first time in 1839 in the membership lists appended to the Annual Reports.

21. Rudwick (1976), (166).
22. Borlase (1758), (Plates XVII and XVIII); Pryce (1778), (Plates IV and VII).

23. Borlase (1758), (Plate XIX, Fig. IV).


25. See sponsorship lists in Borlase (1758), (xiii-xvi), and Pryce (1778), (pages not numbered).


30. Majendie (1818), (32).

31. Trist (1818), (Plate 4).

32. Minutes of Quarterly Meeting, 25th November 1815, RGSC Minute Book No.1.

33. Paris (1816), (237).

34. Sedgwick (1822), (293-4).

35. 25th November 1814, RGSC Minute Book No.1.

36. RGSC Annual Report 1820.

37. Davies Gilbert, Almanac 17th November 1815, CRO DG 19. This map is still in the possession of the RGSC, although in a poor condition, as it is faded and flaking, having been hung on rollers for many years. It bears no letter or number, but appears to correspond to Series I of the classification of Eyles and Eyles (1938). The chalk outcrop corresponds to Pl.IV.A, the Eskdale and Cheviot granites are absent, as is the Coral Rag. The Bodmin granites are not joined. It is not possible to determine the colour of the centre of the Isle of Man, or of the "Killas", because of fading.

38. RGSC Annual Report 1815.


40. Letter to Davies Gilbert from Colonel Mudge, 31st May 1816, Rogers Family Autograph Collection CRO RP 16/19.

41. List of donations to the Library, Transactions, Royal
42. Majendie did not state which edition of Martyn's map of Cornwall he used, but the most recent had been published in 1784. A larger scale version of this map was not published until 1816.

43. RGSC Annual Report 1816.

44. RGSC Annual Report 1820.

45. RGSC Annual Report 1817.


47. Forbes (1822B). The titles of the four papers were: 'Some account of the geology of the coast between Penzance and Boskenna', 'An account of the geology of the coast from Cape Cornwall to Pendeen Cove', 'On the geology of that part of Cornwall lying to the westward of Hayle and Cuddan Point', 'On the geology of west Cornwall (Part 2)'.

48. Forbes (1822B), (Plates V and VI).

49. Carne (1822B), (290-358).

50. Carne (1822B), (319).

51. Forbes (1822B), (263-4).

52. Forbes (1822B), (279-80).

53. Minutes of Anniversary Meeting 6th October 1818, RGSC Minute Book No.1.


55. R W Fox 'On a proposed new method of drawing mining maps and sections', reported as read in RGSC Annual Report 1822.


58. DNB.

59. There were no entries in the Minute Book between November 1823 and December 1827, when Boase resigned as secretary. No pages have been cut out between these records.

60. H S Boase (1827), (166-96, Plate opp. p.166). A map,
accompanying Carne (1827B), (Plate opp. p.208) contained no geological information, although it did have engraved numbers referring to descriptions of granite etc in the text of the paper.

61. RGSC Annual Report 1827.
62. Royal Cornwall Gazette 18th October 1828.
63. Royal Cornwall Gazette 28th February 1829.
64. RGSC Annual Report 1829.
66. RGSC Annual Report 1830.
67. H S Boase (1832).
68. 'Treasurer's Report', RGSC Annual Report 1833.
69. H S Boase (1832), (167).
70. H S Boase (1832), (456).
71. H S Boase (1832), (230).
72. H S Boase (1832), (384). A very similar statement can also be found on page 425.
73. H S Boase (1832), (474).
74. H S Boase (1832), (335).
75. H S Boase (1832), (238).
76. Boase's new terminology was described in detail in H S Boase (1832), (369-426).
77. DNB.
78. DNB.
79. Extract of a letter to Mr Mantell (nd), WSRO (H), 2, Pt.11/1403.
80. WSRO (H), 2, Pt.7/963.
81. Copy of letter from Hawkins to W J Henwood 16th February 1833, WSRO (H), 2, Pt.8/973.
84. Minutes of the 20th Anniversary Meeting, 30th August 1833, RGSC Minute Book No.1.
85. H S Boase (1834).
88. Anniversary Meeting 30th August 1833, RGSC Minute Book No.1.
89. RGSC Annual Report 1833.
90. Royal Cornwall Gazette 25th October 1834.
91. C W, G C and F Boase (1876), (col.20).
92. West Briton 21st April 1837.
93. RGSC Annual Report 1835.
94. RGSC Annual Report 1838.
95. West Briton 9th September 1836.
96. For De la Beche's visits to the Fox family, see Pym (1883).
97. For the assistance of Canon Rogers, see Rogers Family Autograph Collection, 1, CRO RP 16/4. For a meeting between Henwood and De la Beche in Devon, see WSRO (H), 2, Pt.8/1024.
98. De la Beche (1839), (xxiii-xxviii).
99. RGSC Annual Reports 1834 and 1836.
100. Forbes (1822B), (243).
101. West Briton 9th September 1836.
102. See for example, Maton (1797) (152-68) and Warner (1809), (96-7).
103. McCartney (1977), (2); Stafford (1989), (4).
104. De la Beche (1839), (566-7).
105. Laudan (1977), (532).
106. Laudan (1977), (533).
107. Laudan (1977), (535-6).
108. Watson (1897), (36).
109. Watson (1897), (37).
110. Watson (1897), (44).
111. Turner (1829), (13).
112. Goddard (1929), (37).

113. Goddard (1929), (39).


117. Buddle (1831).

118. Buddle (1831), (Plate XX).


120. Morrell (1983), (235).


123. Quoted in Morrell (1988), (167).

124. Morrell (1983), (239-40). Wood (1987), (20) suggests that little progress was made towards completing the Lancashire end of the section.
There have been many different definitions of mineral veins proposed by different writers; one of the most straightforward, and one which is nearly contemporary with the foundation of the RGSC, was that of John Taylor, Treasurer of the Geological Society of London, and a leading mining entrepreneur of the early 19th century. In his 'Report... on mineral veins' given to the British Association for the Advancement of Science in 1833, he wrote:

The clearest idea of a vein will be obtained by imagining a crack or fissure in the rocks, running in nearly a straight line, extending to great and unknown length and depth, and filled with various substances.

He made it clear that he did not include stratified deposits, such as coal, in this description. In Cornwall the term "lode" was frequently used for an ore bearing vein. (Figure 18 shows a modern version of a map giving the location of mineral veins in Cornwall.)

From the very beginning of its history, the RGSC made serious attempts to develop a scientific study of the mineral veins of Cornwall. The proposals formulated by the society in the first years of its existence included studies of the relative ages of veins, and the origin of stream tin; later, in 1829 a comprehensive survey of the Cornish mines was begun. There were also investigations of phenomena which had relevance to the study of mineral veins, especially the high temperatures deep within mines.

There were good economic reasons why knowledge about veins and
their location was important to many members of the RGSC. Mining of metalliferous ores was the major economic activity in Cornwall until the end of the nineteenth century, and many of the gentry and members of the business community derived a substantial portion of their income from the mines and ancillary industries (see Section 3.2). A quotation, from the 1890 Presidential Address to the RGSC by Sir Warington W Smyth, made overt reference to the subject of economic gain, suggesting that these reasons remained valid for most of the 19th century:

Of the various topics coming within the purview of the Royal Geological Society of Cornwall, none has more deservedly claimed the interest of the members than those connected with the formation and general character of the lodes or mineral veins... There is... strong practical inducement to search out the truth, for the discoverer of the real secret would make the fortune of himself and his friends.

John Ayrton Paris, in his introductory address to the prospective members in February 1814, had also emphasised the utility of geology, and its application to mining. Some of his statements on this subject have already been quoted in previous sections, but it is worth repeating that he told the prospective members:

It was [geology's] application to the Art of Mining which rendered this science so highly interesting to the respectable Assembly he had the honour of addressing. The success of this Art came home to the business, and Bosom of every Gentleman present.

He also reminded them that:

...at Huel Boys Mine the metallic lode had been dislocated by a cross course and lost, but by the happy application of geological principles, it had again [been] recovered at the distance of 60 fathoms!!

There were also theoretical reasons for the attention paid to
veins, for investigations which were intended to locate new sources of ores might also have led to greater knowledge about their mode of formation. Sir Humphry Davy, in a paper which he sent to the society in 1815, hinted at both the economic and the theoretical reasons for studying them:

Cornwall may be regarded... as the Country of veins. It is in veins that the most useful as well as the most valuable minerals generally exist; that the pure specimens are found which serve to determine the mineralogical species, and that the appearances seem most interesting in their connexion with geological theory. Thus veins, which now may be considered in the light of the most valuable cabinets of nature, were once her most active laboratories; and they are equally important to the practical miner, and to the mineralogical philosopher.

As well as shedding light on mineralogy, the study of veins had relevance to the debate between Huttonians and Wernerians. Some of the differences between these two schools of geological thought could be seen in their ideas about the formation of veins. There were two particular problems: the origin of the fissures which contained the ores, and the source and mode of concentration of those ores. The followers of Hutton thought that veins were formed subsequently to the rocks in which they were to be found, the ore and gangue minerals having been injected into rocks by the action of heat, and the fissures being created by those processes. The Wernerians thought that the minerals were precipitated from the waters which had covered the earth in its early history, becoming concentrated in fissures which had formed as the continents contracted and dried out. Cornwall was particularly well suited in geological terms to test the differences between the two schools of thought, because of its veins and granite outcrops; the latter were also described by some Huttonian geol-
logists as having been formed by the action of heat. Joseph Carne, in a paper read to the RGSC in 1818, said of this controversy:

The original formation of veins is a subject on which the two great parties which now compose the geological world, are as distant from each other as the surface of the earth is from its centre...

John Taylor, in his 'Report' to the BAAS referred to above, gave three reasons why veins should be studied. His first two reasons, economic and intellectual, were similar to those discussed above, but he also argued that the subject could be used to justify the utility of the study of geology:

...thirdly, in relation to the question sometimes proposed as to the usefulness of geological science, the most ready answer may be given, if it be considered that this inquiry will relate to subjects of practical utility, in which mankind are universally and largely interested.

Religious reasons may have been important to some, as greater knowledge would lead to more understanding of God's work. An argument used in some of the papers on mineral veins was that God demonstrated his benevolence to man by concentrating minerals of economic value in workable deposits. The Rev William Buckland wrote in 1836: "many of [the actual dispositions of the Materials of the Earth] afford abundant proofs of wise and provident Intention".

The location of the RGSC in Cornwall, and in a part of that county where tin mining was particularly important, was a sufficiently valid reason for the emphasis on the study of mineral veins. But this subject may also have assumed importance because the primary interests in geology in the early
part of the 19th century were subjects that were not easy to follow in Cornwall. Neither stratigraphy, nor studies of fossils, at that time the dominant concerns of the Geological Society of London, were thought to be relevant in Cornwall before the late 1830's. The "killas", or clays and shales, were believed to be primitive in origin, and it was not until the Devonian strata in Devon had been identified by De la Beche, Sedgwick and Murchison, that careful attention began to be paid to the similar sedimentary sequences in Cornwall.  

With the notable exception of the "Delabole butterfly" (Spirifer verneuili), which had been identified by J J Conybeare, few other fossils had been recognised in Cornwall until Charles Peach made his discoveries near Gorran in about 1836, and De la Beche began his geological survey of the county. Thus the Penzance Geological Society, seeking for subjects of interest and relevance to be studied by members, was not able to follow the pattern set by the Geological Society of London, and had to find its own fields for study. John Hawkins wrote about this problem in a paper sent to the RGSC in 1821:

...the absence of all organic remains in [the primitive] masses deprives us of the means of tracing with sufficient precision, their relative antiquity... We have none of that anomalous nature, which seem to connect the highest and lowest members of the great series... Our school of geology, in fact, must be regarded as deficient in the materials towards a general and comprehensive system of instruction.

6.1 Knowledge of mineral veins in Cornwall in the early 19th century

There are good sources where information is easily available about the general state of knowledge of mineral veins in Britain at the beginning of the 19th century; the 'Report' by
John Taylor, already referred to above, is a useful summary of the ideas current in the early part of the 19th century. This account will focus on the Cornish mineral veins, and the attempts made to study them.

Continental Europe, and particularly Germany, was the most important source in Cornwall, and in other parts of Britain, for information about mining and mineral processing throughout the 17th and 18th centuries. Much of the technology used in Cornish mines at the start of the 19th century had its origin in Germany (see for example Section 7.1, for the use of explosives in Cornwall). However when it came to theory about the formation and location of veins, there seem to have been fewer direct transfers of ideas from abroad until the end of the 18th century, when the ideas of Werner became widespread.

Cornwall was visited regularly by continental mineralogists and mining specialists, many from the mining academies. In 1679 Dr Johann Joachim Becher, a German mining engineer and mineralogist, had been invited to Cornwall to advise about mining and smelting, and while in Truro had written his Alphabetum Minerale. Eighteenth century Continental visitors to Cornwall with knowledge of mining had included Rudolph Raspe and A G Jars, author of Voyages Metallurgiques en Angleterre (1781). There were inevitably fewer contacts during the period when Europe was cut off by the Napoleonic Wars; although émigrés from France made contributions to mineralogical studies in London (eg. the Compte de Bournon), there is no evidence that they were influential in Cornwall (see also Section 8).
One of the more widely read 18th century Cornish natural philosophers was the Rev William Borlase. He seems to have been little influenced by German traditions, but relied on English natural philosophers, such as Hooke, Woodward and Whitehurst, who had included comments on the origins of ore minerals in their writings. Most of these writers belonged to the peculiarly English school, which emphasised the importance of natural theology, and also the role of the Deluge in shaping the present surface of the earth. Woodward, in 1723, had attributed fissures and the metallic ores which could be found concentrated in them to the final stages of the Deluge:

The metallic and mineral Matter, which is now found in the perpendicular Intervalls of the Strata, was all of it originally, and at the Time of the Deluge, lodged in the Bodies of those Strata; being interspersed or scatter'd in single Corpuscles, amongst the Sand, or other Matter, where of the said Strata mainly consist. That it was educed thence, and transmitted into these Intervalls, since that Time; the Intervalls themselves not existing till after the Strata were formed, and the metallic and mineral Matter was actually lodged in them; they being only Breaches of the Strata, and not made till the very Conclusion of the Catastrophe, the Water thereupon withdrawing again from off the Earth.

In the Natural History of Cornwall, Borlase devoted eleven of his twenty six chapters to descriptions of stones, metals and the veins of his county. In the chapter on lodes he described his own ideas about the origin of metallic ores and the fissures in which they were to be found. He accepted that a universal Deluge had occurred, but disagreed with Woodward that fissures could be attributed to it:

Others think [the fissures] so many breaches of the strata, made at the conclusion of the universal deluge;... but that the lode was prior to the flood, the shodes [loose stones], which have been dispersed from the top of the lode
by the flood, incontestably shew; and that the fissure must be prior to the lode it bears, is as evident as that the cabinet must have been made before the jewels could be inclosed and laid up in it...

First then those fissures are no more, as they seem to me, than the necessary consequences of the first settlement of matter, when it was divided into wet and dry, solid and fluid...

In these fissures, the several ingredients, which form the richest lodes, by the continual passing of waters, and the mentrua of metals, are educed out of the adjacent strata, collected, and conveniently lodged in a narrow channel [sic], much to the advantage of those who search for and pursue them;...

He did however attribute dislocations of the strata to the Deluge, but of the origin of tin he wrote:

Tin in its natural state and hardest bed must, I should think, be reckoned coeval with the creation...

Twenty years later a work specifically devoted to Cornish mining was published by a Redruth surgeon, William Pryce. Much of his information was obtained from the miners of the area around Redruth, and his explanations of the origins of ores were derived from them:

It is reasonable to conclude, that Metals were made and implanted in veins at or very soon after the creation of the world.

The works of both Borlase and Pryce were begun at their own initiatives, although both relied on sponsorship to cover the costs of publication and obtained support from most of the gentry in Cornwall; Borlase also recruited many sponsors from outside the county. There were no co-ordinated undertakings in Cornwall, or in England, to sponsor investigations into mining, or mining exploration. An attempt to set up a Cornish Mining Society in 1792 had apparently been unsuccessful (see Section 2.1.1). The Geological Society of London did little
to promote the practical study of ore minerals; apart from papers on Cornish mining by William Phillips and John Taylor, there was scant attention paid to this subject in the first four volumes of the society's Transactions.²⁴ No journal exclusively devoted to the mining industry was published in Britain before the Quarterly Mining Review (1830-7), and the weekly Mining Journal (1835-); this contrasts poorly with the continent where publications such as the French Journal des Mines (1792) had been in existence from a much earlier date. A suggestion by Leonard Horner that the Geological Society of London should publish in a form similar to the French Journal had not found support,²⁵ and John Taylor's Records of mining had only one edition, in 1829.²⁶

German Mining academies, especially that at Freiberg where A G Werner was Professor of Mineralogy, became important centres for the teaching of mineralogy and geology, as well as mining. There was no comparable institution in Britain until the establishment of the Royal School of Mines in London in 1851. A few Cornish men were able to visit Mining Academies abroad, although these were the sons of gentlemen who could afford the cost of travel and study abroad. Two such men, both members of the RGSC, who had studied at Freiberg under Werner, were John Hawkins and J H Vivian (see also Section 8). There is a suggestion in the Dictionary of National Biography, under the entry for Joseph Carne of Penzance, that Werner visited him in Cornwall, but this visit seems unlikely to have taken place.²⁷

John Hawkins, the younger brother of Sir Christopher Hawkins
an owner of land and mines, had made visits to Freiberg towards the end of the 18th century, in order to study the methods of the German mining engineers. His relationship with Werner became sufficiently close for the Professor to bequeath him a gold snuff box with his portrait. John Hawkins made attempts to persuade his brother of the superiority of some of the German methods, hoping that Sir Christopher might introduce them into his own mines. In 1808 John wrote to his brother:

As for the German method of stamping and dressing their ores, so convinced am I of its superior excellence that I should not be very surprised to see it in a few years very generally followed even in Cornwall.

In 1790-1 he had made his own study of Cornish mines, and in 1791-2 had sent out a series of questions on practical mining to "the most intelligent captains of our mines", seeking information about mineral veins. He stated that the queries were "the practical result of a much longer attention to the subject, begun in Saxony under the guidance and instruction of Werner, and continued in Bohemia and Hungary". It is regrettable that Hawkins made little attempt to publish any of the information that he had gathered, until he was offered the opportunity of using the medium of the Transactions of the RGSC. Several of his papers included in the first four volumes were based on the studies that he had made in Cornwall and on the continent in earlier years.

There was also formal government support for mining in France, where the École des Mines had been opened in Paris in 1783. In the autumn of 1823 the RGSC was visited by two members of
the École des Mines, who were accompanied by the Professor of Mineralogy at Munich; a visit made on the recommendation of Sir Humphry Davy: 33

The Secretary then stated that the Society had been honoured with a visit from Charles Schmitz Professor of Mineralogy at Munich; and also by Elie de Baumont [sic] and C Dufreni from the School of Mines at Paris. These mineralogists were recommended to the attention of the Society by Sir H Davy, and they expressed themselves gratified at the progress we had made... Messrs Beaumont and Dufreni proposed scientific intercourse and exchange of Transactions and minerals with the School of Mines.

Although Transactions continued to be exchanged throughout the 19th century, there is no record of any other contact with the Paris institution. 34

By around 1800 there was fairly extensive empirical knowledge of the Cornish mineral province. There was however little comprehension of the genesis of ores, and no map was available to show the extent of the mineralized areas (see Section 5.3). Joseph Carne wrote in 1824: 35

... until little more than half a century ago, the art of mining in Cornwall, (for it could scarcely be called a science) as well as the sciences most nearly connected with it, had continued almost stationary... With few exceptions, the mode which had been pursued by their ancestors was almost superstitiously followed by the miners...

I am not aware that much improvement has taken place in the mode of searching for lodes, unless it is by driving across the country from north to south, or vice versa... for want of proper attention to the connexion which appears to exist between the lodes and the rocks which they intersect,... very large sums of money have been spent to no purpose.

6.2 The research programme of the RGSC 1814-1840

It has already been mentioned that one of the earliest subjects raised at a meeting of the RGSC was the location and
origin of mineral veins (see p.115). At the first Quarterly Meeting of the society, in May 1814, a method of gathering information about veins was proposed:

At the same meeting a series of questions relative to the situation and direction of Lodes were presented by Jos. Carne, Esq. The Society resolved to print them, and to circulate them in the mining districts, with a request to have them answered.

A copy of the questions does not exist in the society's archives, nor has it been possible to locate one elsewhere. It is clear that they were printed and circulated, for the Annual Report for 1815 listed among the papers read: 'Answers to a printed list of questions circulated by the Society' by Mr J Davy of Wheal Alfred. The same Annual Report referred to "Answers to geological questions" by John Stephens, whose name was included as an Associate Member in a list of members printed in 1815. There were no further references to the questions, nor was any summary of the information obtained printed in the Transactions. The exercise however prompted John Hawkins to send a list of his own 'Queries' which he had circulated to mines captains in 1791-2 (see above), to aid the society in its investigations.

Papers read at meetings in 1814 included 'An account of the gold found in the stream works of Ladock' by Sir Christopher Hawkins, and 'The geological history of the Relistian Mine' by Joseph Carne. Carne became one of the most reliable contributors of papers to the society. The subjects addressed by him included silver mines (1815), copper mines (1816), the discovery of phosphate of iron at St Agnes (1817), and lead veins and "Cornish petroleum" (1820). He also made a thorough investigation of the mineral deposits of the St Just
area (see Section 5.3).

Volume I of the Transactions (1818) contained several important papers on mineral technology, including 'Observations on the processes for making the different preparations of arsenic, ...and on those for preparing smalt or cobalt...' by J H Vivian, and 'On a process of refining tin' by John Hawkins. Apart from the list of 'Queries' proposed by John Hawkins referred to above, there was nothing relevant to the subject of mineral veins. Volume II (1822) however contained several such papers.

The most important was by Joseph Carne, 'On the relative age of the veins of Cornwall', read in October 1818. This was an attempt to classify the many kinds of veins found in Cornwall, and to attribute a relative age to them. An exercise of this kind had already been tried by William Pryce, in a more limited way. Carne explained how he intended to improve on this, and from whom he had derived his ideas:

...all parties [Wernerian and Huttonian]... are agreed on this important principle: that a vein which is intersected, or traversed, by another, is older than the vein by which it is traversed. ...Pryce was, I believe, the first who plainly laid it down in his Mineralogia Cornubias. It is the principle on which Werner lays the greatest stress, in his New Theory of the formation of Veins: and on the same principle, I would make a humble attempt to ascertain the relative age of the veins of Cornwall.

Carne first distinguished two main categories of vein: "contemporaneous veins" and "true veins". (He also included a class of "doubtful veins", in which he placed "granite veins in slate" and elvans.)

The "contemporaneous veins" he des-
cried as "formed at the same time as the containing rocks". 45 Few of them contained minerals of economic importance, although they could be useful sources of collectable minerals such as opal and garnet. 46 He was unable to make any reliable estimate for the ages of these veins, saying only that: 47

...although [these veins] may all be contemporaneous with the rocks which contain them; it does not follow that they are all of the same age: ...their ages must be as different as those of the containing rocks.

The "true veins" included all the metal bearing lodes. Carne classified these according to age, using the principle alluded to above. A simplified version of his classification is shown in Table 5, overleaf.

As well as dating veins by the principle of intersection, Carne made a second important observation, for he recognised that faulting, indicated by the presence of clay, had occurred only in the later stages of vein formation: 48

But I think another principle may be deduced... viz. that veins which contain the greatest amount of flukan or clay, are generally found to traverse those which contain a less quantity, or none at all of that substance...

He avoided any speculation about the origin of ore minerals: 49

I have purposely abstained from speculating on the manner in which the contents of the veins were originally placed in the fissures which contain them.

In doing this he probably was following the advice given by John Hawkins, in his explanation of his list of 'Queries', printed in Volume I of the Transactions. Hawkins had written: 50

...a great mass of well ascertained facts must be collected, before we can draw any certain conclusions respecting the origin of mineral veins. I am of opinion, however, that when this is accomplished, we shall have gained a step of no small importance towards a knowledge of the formation of the earth, if we do not stand on the very threshold of the edifice.
TABLE 5

CLASSIFICATION OF TRUE VEINS (1818)

(Joseph Carne 'On the relative age of the veins of Cornwall', Transactions, Royal Geological Society of Cornwall, II, 1818, pp. 49-128).

<table>
<thead>
<tr>
<th>CLASS</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST CLASS</td>
<td>the oldest tin lodes&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>SECOND CLASS</td>
<td>the more recent tin lodes</td>
</tr>
<tr>
<td>THIRD CLASS</td>
<td>the oldest east and west copper lodes</td>
</tr>
<tr>
<td>FOURTH CLASS</td>
<td>the contra copper lodes&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>FIFTH CLASS</td>
<td>cross courses&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>SIXTH CLASS</td>
<td>the more recent copper lodes &amp; lead veins</td>
</tr>
<tr>
<td>SEVENTH CLASS</td>
<td>the cross flukans&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>EIGHTH CLASS</td>
<td>the slides&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Carne's definitions of the terms flagged were: (p85)

<sup>a</sup> lode - a metalliferous vein

<sup>b</sup> contra lode - the direction is from 30° to 60° from east to west

<sup>c</sup> cross courses - veins whose direction is not more than 30° from north to south

<sup>d</sup> cross flukans - having the same direction as the cross courses (flukans - veins composed of soft clay)

<sup>e</sup> slides - veins of slimy clay, greatly inclined having generally an east and west...direction
Carne's paper on the relative age of veins was important because, although he stuck firmly to fact gathering, it was the first proper attempt in Cornwall to collect detailed information about the many types of veins and to categorise them according to their mineral content, age and trend. The paper was cited frequently by later authors; John Taylor wrote that it held a "distinguished place" among those written on the subject of veins. 51 De la Beche wrote of it: 52

Whatever may be thought of the necessity of some of the eight distinctions above made, the value of the memoir itself cannot be doubted, embodying as it does a great mass of facts, and having, as Mr Robert Were Fox justly observes, formed an epoch in the records of Cornish mineral veins, in proof of which it is merely necessary to glance at what had been previously published on the subject, and the frequent use which has been subsequently made of it.

Carne had made it clear that not all mineral veins in Cornwall were of the same age, raising the question of whether fissures might also have been formed at several different periods. John Hawkins attempted a partial answer to this problem in two papers also included in the second volume of the RGSC Transactions: 'On the intersection of lodes in the direction of their dip or underlie' and 'On the phenomena of intersected lodes, and the legitimate inferences which may be drawn from them'. 53 In 'On the intersection...', Hawkins deduced that because of the many different intersections of the lodes at Wheal Peever, there must have been at least three different periods when disturbances in the crust had taken place: 54

If lodes were originally fissures occasioned chiefly by the uneven resistance of the strata to the pressure of gravity, as Werner supposes; a shifting of the opposite sides of the fissure must necessarily have been the result of this subsidence in every instance...
At a period subsequent to this, another disintegration of the strata, under very different circumstances, appears to have taken place here;...

I have now to mention a revolution which, at a period still later, has caused another transposition of the strata, together with all their contents, and created still greater confusion...

Because of his adherence to Wernerian ideas, Hawkins may have felt unable to draw from these deductions the conclusion that not all lodes could have been formed by precipitation from a primeval ocean. In 'On the phenomena...', he referred again to several periods of lode formation:55

Whatever may have been the nature of that power which has occasioned those fissures in the strata which we call lodes; it appears to have acted at various intervals of time;

In the same Volume of the Transactions, Hawkins described two special types of metal ore deposits, "tin floors" and stock-works, comparing the latter with similar deposits in Germany.56

There were also four papers in Volume II on the subject of the temperature within mines; two by R W Fox, read in 1819 and 1820, one by John Forbes read in two parts in the same two years, and one by M P Moyle, read in 1822.57 These were followed in 1827, in the third volume of Transactions, by two more papers, by T F Barham and R W Fox.58 These papers were all designed to try to determine whether a heat gradient existed within the earth; similar experiments had been carried out elsewhere in England and on the continent, and more were made by John Davy, for his brother Sir Humphry, in Cornish mines in 1820.59 All the RGSC authors, with the exception of M P Moyle, came to the conclusion that raised temperatures below ground could not be accounted for solely by human acti-
vities, and that there must be even higher temperatures towards the centre of the earth. Robert Hunt, in 1887, suggested that another motive for this study was to see whether there was a connection between temperature and the presence of minerals;\textsuperscript{60} Henwood was later to comment on differences between the temperatures of copper and tin veins.\textsuperscript{61} Some of the authors also speculated about the cause of heat within mines, a matter which had relevance to the debates between Huttonians and Wernerians, and could have had a bearing on the origin of the mineral veins. In the last of those papers, read in October 1827, R W Fox made a prediction that was to assume an important role in his later work on the origin of veins (see below): "it seems highly probable, that electricity may be a primary exciting cause of the high temperature of the earth".\textsuperscript{62}

The origins of mineral veins became an important matter for discussion at meetings of the British Association for the Advancement of Science from its inception, and members of the RGSC played an important part in the debates. (The role of R W Fox will be discussed in Section 6.3 below.) At Oxford in 1832, John Taylor called:\textsuperscript{63}

\textit{...the attention of geologists to the collection and arrangement of vein-stones, and to an accurate examination of their connexion with the rocks in which they occur [which were important] both in respect to geological theory and economic utility.}

In the ensuing discussion, Dr H S Boase took part, and argued that "the production of veins was coeval with the formation of the rocks".\textsuperscript{64} He found that few others agreed with him, and in 1833 at Cambridge, Taylor criticised his methods, saying that Boase had "purposefully refrained from making enquiries
at the mines", having relied on cliff and quarry exposures. Boase's sole supporter was W J Henwood who, in 1837 at Liverpool, delivered a paper on "heaves" (faults) in Cornish mines, in which he claimed that "the theory of mechanical disturbance...would not explain the phenomena as displayed".

A subject to which particular attention was paid by the RGSC in the 1820's and 30's was the origin of stream tin, from which was produced the refined product known as grain tin. This was found in surface deposits, usually beneath the beds of rivers and streams, and had been the earliest resource to be worked in the county. This type of tin was particularly pure, and was much in demand for use in dye works, for pottery glazes, etc, and consequently it could command a higher price than the tin from deep mines; it was also more economical to extract. By the beginning of the 19th century such deposits were becoming worked out, and new ones were increasingly difficult to locate. It was therefore a matter of economic importance that efforts should be made to understand their mode of formation, in order to help in discovering fresh sources.

In 1823, the Council had recommended this study to members in its Annual Report:

They also take this opportunity of recommending the Tin Stream Works of Cornwall to the attention of the Society, and especially to those Members who reside in their vicinity, as a subject that has not yet undergone the investigation to which it is entitled; and concerning which they apprehend there is still wanting a satisfactory explanation.

This wording is almost identical to that of a paragraph in Carne's paper 'On the mineral productions and geology of the
parish of St Just' (read in 1821), so it is possible that he initiated this research. John Hawkins had however also sent to the society a paper by the late Philip Rashleigh on the subject of tin stream works, to which Hawkins had added his own comments: both were read in 1819.

A paper by W J Henwood, 'On the stream works of Cornwall', was delivered in 1828, presumably in response to the Council's request, and he followed it with another in 1829. These papers were printed in the fourth volume of Transactions (1832), together with one by John W Colenso, read in 1829, and two by Joseph Carne, both read in 1830. In 1835 a paper by Mr Thomas Foss, 'Remarks on the stream works at St Erth', was read, although no details of this remain.

Much of the speculation on the origin of stream tin was concentrated on trying to determine whether its original source was in the veins, and whether it had reached its present location as a result of the Deluge. The investigators were therefore combining theoretical enquiries with practical attention to locating the sources which might disclose new deposits. W J Henwood doubted whether most of the deposits had their origin in the Deluge. He wrote in 1828:

If the tin-ore found in stream works were torn from veins in the neighbourhood by diluvial action, an immensely larger mass of the contiguous strata must have been simultaneously removed; but the quantities occurring in the stream works, bear but a small proportion to the masses of the tin-beds.

[These facts and others] lead me to the conclusion, that of our large deposits of stream tin-ore, the lower portions are of ante-diluvial formation; whilst the higher parts of them, with the whole of some of smaller extent, and the mixture of trees, nuts, leaves, sand, gravel, pebbles, &c are the true diluvium.
Joseph Carne disagreed with this interpretation, but also with the ideas of Lyell about uniformitarianism, newly published: 75

...I may perhaps be allowed to remark that the stream-works of Cornwall appear to me to be most decidedly opposed to the doctrine that 'all the changes which have taken place on the earth's surface have arisen from causes which are still in operation'. They, on the contrary, furnish the strongest proof of one sweeping inundation, the effects produced by which have never been repeated by any subsequent flood. In many of these deposits there are several alluvial beds resting on the diluvial detritus.

In his second paper in the same volume, Joseph Carne argued that the stream tin must have come from veins, but that it had been worked by water to remove impurities such as arsenic. 76 He also explained the absence of copper ores in the deposits, by arguing that these ores were "found far deeper in the veins", and hence could not have been eroded by water and deposited elsewhere. 77

By the end of the 1820's, the investigations of mineral veins by the RGSC became concentrated in two main directions, each associated with an individual member of the society. The first subject, electromagnetism within the earth, was studied by R W Fox. Although some of Fox's work was presented to the RGSC, he published his ideas much more widely, and to follow their progress it will be necessary to look at all the institutions with which he became involved. The second individual was W J Henwood, who embarked on a survey of the mines of Cornwall, at first under the sponsorship of the Fox family, and later with the backing of the RGSC. Both these subjects will be discussed in separate sections.
6.3 R W Fox and the electromagnetic properties of mineral veins

Robert Were Fox was a member of the Quaker Fox family of Falmouth. He was one of the founding members of the RGSC in 1814, and in 1833 played a leading role in the foundation of the Royal Cornwall Polytechnic Society (see Section 3.1.2 above). His geological interests tended towards what would today be called geophysics, for he had a particular interest in geomagnetism and electricity, and between the years 1829 and 1842 wrote a series of important papers on electromagnetism in mineral veins. It is possible to trace the development with time of his ideas about veins in various different papers, and substantial quotations from his work will be used.

Serious studies of the applications of electricity had become possible with the invention in 1800 of the Voltaic pile. Humphry Davy, another Cornishman, had used the new invention to make important discoveries in chemistry, in particular the electrolysis of the alkali salts, and his work was well known in Cornwall. Davy had referred to the possibility that electrical action could modify the surface of the earth, in his Elements of Chemical Philosophy:

As electrical changes are almost constantly taking place in the atmosphere, and as the different substances composing the exterior of the globe, bear different electrical relations to each other, it is very probable that many of the chemical changes taking place on the surface, are influenced by the action of weak electrical powers: such as the decomposition of the surfaces of rocks, the modifications of soils, the formation of acid and the development of alkaline compounds; and the mutual agencies of the elements in the earth, the sea, and the atmosphere, may be assisted or modified by the circumstances of general electrical action.

Davy had taken this idea a step further in one of his lectures
[the central heat of the earth] may be accounted for by supposing the interior of the globe composed of the metals of the earths, which the agency of air and water might cause to burn into rocks; and even the re-production of the metals may be conceived to depend upon electrical polarities in the earth;

Fox was to use some of Davy's ideas when trying to explain how mineral ores could have become concentrated in veins, although he never referred directly to any of Davy's works in his papers on electromagnetism. There are no indications that the two men ever knew each other, or corresponded. (Searches of the Davy Collection at the Royal Institution have not revealed any relevant letters, etc.)

Fox was also aware of the work being done by Oersted and Ampère, which linked magnetism with electricity, and he attempted to incorporate magnetic forces into his theory. The question whether Fox was aware of the work being done on electromagnetism by A C Becquerel in France was to assume importance in a dispute between Fox and Henwood (see below Section 6.4). In most of his papers Fox used the term "electro-magnetism" to describe the general effects that he was investigating, probably because he wished to stress the connection between electricity and magnetism. However, he changed his ideas about the particular form of electricity that he thought was responsible for deposition of ores, as his experiments progressed. At this period, the different ways in which electricity manifested itself were not understood fully, and it was thought that Voltaic, contact, and thermoelectricity etc, might be separate types of "imponderable fluid".
J H Collins, the author of a *Sketch of Fox's life* (1878), said that he had begun his work on metalliferous veins in 1829, but it seems clear that he was already thinking about the connections between electricity and mineral veins much earlier. It is likely that he was led to investigate electricity in mineral veins through the experiments he had made on the temperatures in mines, although it has not been possible to locate his Notebooks which were seen by Collins in 1878. Fox had become convinced by his experiments that very high temperatures existed within the interior of the earth, and he initially attributed this internal heat to electrical forces in its interior. In a paper published in *Annals of Philosophy* in 1822, 'On the temperature in mines', he wrote:

If electricity, for instance, be evolved when several different mineral substances are brought into contact, and likewise in the process of crystallization, &c, may it not in connexion with the strata and veins, and the almost distinct portions of water which abound in the earth, also act its part on a larger scale, and not only excite heat, but contribute to produce the extraordinary aggregation and position of homogeneous minerals in veins, &c, and the beautiful order which exists even under the surface of the earth.

In 1836 Fox gave his own account of how he had come to study electromagnetism in mineral veins:

In 1827, I again alluded to the subject [of metallic veins], and to the apparent analogy between electro-magnetism, and the generally prevalent direction of the principal metallic veins, nearly at right angles to the magnetic meridian. Between two and three years afterwards I commenced my experiments on the electro-magnetic properties of metalliferous veins, and proved the reality of the existence of electricity in them.

In his first paper specifically about mineral veins, printed in the *Philosophical Magazine* in July 1829, Fox described the phenomena which he intended to investigate.
It appears to be a question worthy of investigation, how far the internal structure and temperature of the earth may be connected with electricity, magnetism, and with the meteorological phenomena observable at its surface.

He also noted that veins in Cornwall and Devon were either "coincident with the magnetic meridian, or at right angles to it". He described some experiments that he had made in mines, and claimed to have been able to detect electrical currents in lodes; his apparatus was described by Collins:

Small plates of sheet copper were fixed to the selected parts of the vein (the "ore-points") by wooden props extending across the level, or, occasionally by copper nails. The points were connected in pairs by copper wire 1-20th of an inch diameter, and a galvanometer was introduced at some convenient part of the circuit... Some of the experiments were continued for 10 or 11 hours together...

An illustration of this apparatus was included in a Plate appended to Fox's 1836 paper in the Report of the Royal Polytechnic Society of Cornwall.

Two papers by Fox on electromagnetism appeared in 1830, the first communicated to the Royal Society by Davies Gilbert, and subsequently printed in the Philosophical Transactions, and also in Journal de Géologie, the Edinburgh Journal of Science and Silliman's Journal. In the first paper, Fox gave details of Cornish mines in which he had made his experiments, listing twelve by name, and referred also to mines in "Mexico, Guatemala and Chili", and to information from Humboldt about other mines, all of which he said bore a "general resemblance" to the Cornish ones. He also discussed the practical relevance of his ideas.

The intensity of the electro-magnetic action differed greatly in different places... In general it was greater... in proportion to the greater abundance of copper ore in the veins, and in some degree perhaps to the depth of the stations... Hence it seems likely that electro-magnetism may become useful to the practical miner in determining with
some degree of probability at least, the relative quantity of ore in veins, and the directions in which it most abounds.

He included a list of various metallic ores, classifying them as "Conductive, Very Imperfect Conductors, and Non-Conductors". 92

The second paper given in 1830 was to the RGSC, at its Annual Meeting in October. Fox first gave a summary of his paper to the Royal Society, saying: 93

In the paper which I forwarded to the Royal Society, I have stated my views of the probable connexion between electrical currents in veins and terrestrial magnetism; and I have also suggested my reasons for considering the various geological theories which have been proposed, inadequate to explain the origins of veins.

The Huttonian doctrines are perhaps more plausible than the Wernerian, and the high temperature which is now generally admitted to exist under the earth's surface, has probably tended to give the former an increased degree of credibility; yet they cannot, I think, be easily reconciled with many ascertained facts; such, for instance as the contents of lodes having a distinct reference to the rocks they traverse... nor do the contents of lodes afford indications of the action of heat...

This was the last paper by Fox published on this subject in the RGSC Transactions. There was a hiatus in publishing by the RGSC between 1832 and 1843 (see above, Section 4.2.3). Fox used other journals instead, including the Philosophical Magazine, the Annual Reports of the RCPS and the Proceedings of the Geological Society of London. After the foundation of the polytechnic Society in 1833, he gave fewer papers to the RGSC, preferring to present his ideas to meetings of an institution to which he gave personal attention. 94 A dispute with W J Henwood, Curator of the RGSC from 1834, may also have affected his willingness to do more for the Penzance society (see below).
The British Association for the Advancement of Science became interested in Fox's work. According to Collins, in December 1831 Fox was asked by Vernon Harcourt, on behalf of the British Association, to make a report on his work on electromagnetism in veins. Collins wrote that Fox replied "that his time was too much occupied, but that Mr W J Henwood might be got to do it". Henwood had assisted Fox in carrying out some of his studies, but had embarked on a survey of the Cornish mines, and it seems unlikely that he would have wanted to postpone this in order to begin a survey for the BAAS (see Section 6.5 below for more detail about Henwood's career). No report on this subject was ever made to the BAAS by Henwood.

The report of the British Association for 1831 had referred to Fox's paper for the Royal Society, and a proposal had been made "that the experiments should be extended to veins which traverse...horizontal and dissimilar strata". If it was further investigation that was proposed rather than a report, and as the types of veins referred to were in areas remote from Cornwall like Derbyshire and Northumberland, this may explain why Fox should have turned down Harcourt's request. His business interests in Falmouth, and his growing family, meant that he had to spend most of his time in Cornwall. In 1833 the Committee of the British Association recommended for further examination "the Electro-magnetic condition of mineral veins". At the Edinburgh meeting in 1834, Fox and John Taylor were made members of a Committee, which was given 100 to investigate "thermometrical observations" in mines, wells, etc. In 1836, Fox was able to apply his methods in two lead mines in County Durham; he reported to the British Association
In 1837 that he had intended to carry out more experiments, but "other engagements have, unfortunately, interfered with the execution of these plans".100

In May 1832 a second paper by Fox for the Royal Society was read; 'On certain irregularities in the magnetic needle, produced by partial warmth, and the relations which appear to subsist between terrestrial magnetism and the geological structure and thermo-electric currents of the earth'.101 This paper showed how he was developing his ideas about the connection between electricity and veins, for he was by now attributing electricity in veins to high temperatures deeper in the earth, whereas previously he had supposed that electricity was the cause of high temperatures. Sir Humphry Davy had shown in 1821 that the conductivity of metal varied with temperature.102 Fox was also aware of the work of T J Seebeck of Berlin on thermoelectricity, published in 1822; Seebeck had shown that a feeble current could be produced if heat was applied to the junction where copper and bismuth had been soldered together.103 The Proceedings of the Royal Society reported that:104

On the hypothesis of the existence of a very elevated temperature in the interior of the globe, it would necessarily follow... that electrical currents would be produced from this cause, taking frequently different, and even opposite directions, and exerting an important influence on all the phenomena of terrestrial magnetism,... The later researches of the author have satisfied him that the directions of these currents are probably much influenced by the geological structure of the globe; which in most cases tend to give them more or less obliquity to the parallels of latitude.

However soon after this, Fox began to abandon the idea that
thermoelectricity was responsible for vein formation, and started to look at chemical causes. He came to realise that circulating currents of water were important agents in the formation of vein minerals, and must have suspected that water could serve the same role in the subterranean environment as it did in a Voltaic pile. In 1833 Faraday had shown that there was a connection between the different forms of electricity, and this may have inspired Fox to look again at the type of electricity which he had been able to detect in mineral veins. In April 1835, Fox gave some details to the Geological Society of London about the possible chemical sources of electricity in lodes, and its role in concentrating metals:

...electricity may have powerfully influenced the existing arrangements of the contents of [the] fissures. ...as the rocks forming the walls of the veins, contain different salts, they would be in opposite electrical conditions, and hence currents would be generated and readily transmitted through the fissures, and in time the metals would be separated from their solvents and deposited in the veins.

He still believed that electrical currents were produced within the earth, and that these could be the cause of the geomagnetic field. At the BAAS meeting in 1835, in Dublin, he gave another paper, 'On the absence of magnetism in cast iron when in fusion'. He referred to observations about the loss of magnetism in materials at high temperatures, first seen by Peter Barlow in 1822, and suggested that:

This experiment may perhaps be considered by those who advocate the existence of a high temperature in the interior of the earth, as tending to strengthen the arguments in favour of the agency of electricity in producing terrestrial magnetism.

By 1836 Fox had nearly completed the formulation of his ideas,
and they were presented in the same year to a number of institutions, including the RGSC, the RCPS, the BAAS, the Redruth Institute, and the Geological Society of London.\textsuperscript{108} Summaries of his paper were printed in several journals, but the fullest version was given in the \textit{Annual Report} of the RCPS.\textsuperscript{109} He wrote that he still felt that his ideas were in need of testing, and said:\textsuperscript{110}

\begin{quote}
I am, however, encouraged to hope, that an extensive circulation of the Report among the miners of Cornwall, may induce many of them to record the results of their experience and observations in our mines; and if so, one object of this communication, however defective it may be, will be accomplished.
\end{quote}

He discussed the formation of fissures, and the circulation of water within the earth, leading to the deposition of ore minerals. He also attempted to explain the observations made in many parts of the world that most mineral veins, including those in Cornwall, were orientated approximately east-west. He wrote:\textsuperscript{111}

\begin{quote}
It is evident...that rocks become conductors of electricity, especially at considerable depths, where the great pressure of the column of water, and the high temperature, combine to introduce moisture into them. If then, the rocks are thus rendered even feeble conductors of electricity, and contain different salts, they are necessarily, exciters of it also...

Ampère has inferred...that the direction of the compass... is due to the circulation of currents of electricity round the globe from the east towards the west... Whether...we regard terrestrial magnetism as the effect or cause of the direction of electric currents, it cannot be doubted that these phenomena are in harmony with each other...

...if fissures happened to have opposite horizontal bearings, and were equally filled with water charged with saline matter, the electric currents would be determined in preference, through such of them as most nearly approximated to the magnetic east and west points at the time. ...[the currents] would act on the saline substances contained in the water, and gradually decompose them, the metal, or base, being determined towards the negative pole, or the electro-
negative rock, and the acid, towards the electro-positive rock.

However slow this process might, at first, have been, the deposition of the metals would cause it to become more and more energetic.

Several more papers were published by Fox on this subject between 1836 and 1842, but most were accounts of further experiments he had conducted to try to improve his arguments. One paper, read first to the RCPS in 1837, described some experiments that he had made on a lump of clay. He found that continued exposure of the clay to an electric current produced laminations with concentrations of ores between them, and argued that "these experiments illustrate the origin of schists as well as mineral veins". In addition to his electrical theory, Fox also paid attention to ideas about the origins of the fissures within which ore minerals were most frequently found. His own personal inspections of lodes in Cornish mines lead him initially to doubt that veins had formed in open fissures; he first stated this in 1829. By the time of his 1836 paper to the RCPS, his ideas had been only slightly modified, so that although he did now accept that fissures might have preceded vein formation, he argued that their widening was progressive.

My objections to the hypothesis of fissures, were however removed, when it occurred to me, that many of them might have been very small at first, and become progressively opened and filled with mineral deposits...

After 1842, Fox started to give most of his attention to the subject of magnetism, a subject which he had been pursuing jointly with his studies of veins; no more papers on electromagnetism in veins were given.
6.4 Reactions to Fox's hypothesis

Because Fox published his ideas so widely, he attracted considerable attention, by no means all of it favourable. Davies Gilbert wrote to Fox, congratulating him on his 1830 paper to the Royal Society. Gilbert's description of its reception by the Royal Society should perhaps be read with a degree of caution, since he was writing to a friend and fellow Cornishman: 116

I believe no paper has been read for many years which excited so great a degree of attention. It was considered by many as likely to form an epoch in Geological Science, and I confidently anticipate your pursuing this path as Humphry Davy did that of galvanism in another form.

The Rev William Buckland also commented on this paper by Fox in his Bridgewater Treatise in 1836, writing: "The observations of Mr Fox seem to throw new light upon this obscure and difficult subject". 117

At the Cambridge meeting of the BAAS in 1833, John Taylor made his 'Report on the state of knowledge respecting mineral veins', and referred to Fox's ideas. 118 Through his business interests in mining in many parts of Britain and in Mexico, Taylor had extensive knowledge of mines. He found that he could not wholly agree with Fox's hypothesis as it was then formulated, stating: 119

....nothing upon which any hypothesis can be built seems, however, as yet to have been proposed; and it may be doubted whether, when this test is applied to masses of ore, the experiment is not liable to many objections. A principal one seems to be, that by the very act by which we gain access to the vein, we lay it open to atmospheric action, and consequently to decomposition. Chemical agency commences, and with it, very naturally, galvanic influences are excited.
Veins containing ores little subject to decomposition have, I apprehend, been found to give little or no indications of this nature.

The Rev Adam Sedgwick also made a study of veins, including those in Cornwall, but he considered the east-west trend which Fox had attributed to the earth's magnetic field, to be at least in part the result of the structure of the rocks and of "mechanical disruption". There is no evidence that Sedgwick attempted to follow up any of Fox's work on electricity in veins, but others did do so. At the British Association in 1837 it was decided that:

...a REPORT should be drawn up on the present state of our knowledge of the effects of Volta and Thermo-Electricity in the production of Crystals and the modification of Minerals Substances...

H L Pattinson did some experiments involving electricity on lead ores in the Pennines, but reported to the BAAS in 1839 that there was "no appreciable effect".

De la Beche began his geological survey of Cornwall in 1835, and one of the people from whom he received most support, both factual and hospitable, was R W Fox (see Section 5.3). In 1836 De la Beche wrote to J S Enys (a neighbour of the Foxes, and son-in-law of Davies Gilbert) about Fox's ideas:

Many thanks for your note respecting Mr R Fox's discoveries. I have, and for some time have had, no doubt that the electro-magnetic theory of the non-mechanical part of the mineral veins was the true one, or at least the most probable of any that has been yet stated on the subject... Press him by all means in your power to stick well to his subject and, now he is about it, to carry it out as far as possible. It is rather a minor point to be pleased with, but I really am highly and particularly gratified that a Cornish man should be the one to put that matter of the filling of mineral veins straight and that it will be put straight by Mr R Fox if he continues his labours I have little doubt.

The following month Caroline, Fox's younger daughter, recorded
Papa read his new theory of 'veins'; De la Beche thoroughly seconds his ideas of galvanic agency, but will not yet yield the point of the fissures being in constant progression; he says they were all antediluvian. They [De la Beche, J S Enys and Sir Charles Lemon] stayed several hours and were particularly charmed with some experiments about tin and galvanism.

De la Beche included a chapter on mineral veins in his Report on the Geology of Cornwall... 'Ch.XII Theoretical observations on the formation and filling of mineral veins and common faults'. He referred to A C Becquerel's Treatise on electricity and magnetism, published in Paris in 1835, saying:

Becquerel seems to have been the first to show that by slow secondary electrical action, caused by feeble currents, a variety of substances are produced which are not formed by common chemistry...

He then went on to discuss various ideas about the origin of mineral veins; Fox's ideas were included as one possible hypothesis:

Mr Robert Fox appears for some time to have been impressed with the belief that electrical action might not only contribute to produce the extraordinary aggregation and position of homogeneous minerals in veins, but also that this action is still kept up in them; and accordingly he commenced a series of experiments on the electro-magnetic properties of mineral veins of Cornwall...

In Cornwall Fox's 1836 paper 'On mineral veins' was greeted with interest, and by some people with enthusiasm. The West Briton reported on the presentation of Fox's ideas to the RGSC in 1836, and on the Rev William Buckland's compliments to the author. The nature of the audience to whom Buckland was speaking, the members of the RGSC and their guests, should however be taken into account, for it would have been composed
of friends and associates of Fox: 128

Dr Buckland, after complimenting Mr Fox very highly on his beautiful and valuable discovery, said that it would go down to posterity with the discoveries of Newton, with whom Mr Fox would be for ever associated. Until March last, said the eloquent Professor, we were all in the dark on the subject of mineral veins - it was the "terra incognita" of Geology - but Mr Fox had illuminated and revealed to us the laboratory of Nature; and her secret operations are now as familiar and intelligible as the commonest and most simple experiments.

Fox read his paper again, to the Redruth Institution in November 1836, and this reading seems to have attracted more popular interest. A correspondent wrote to the Royal Cornwall Gazette in November 1836 asking that the paper be printed in a form that would make it most widely available. (The references to the Transactions of the RGSC seem to be a misunderstanding, as a report of the Redruth meeting, in the West Briton for 11th November 1836, referred clearly to the RCPS.): 129

In the few hasty remarks made in your paper of the 4th inst. on the popular Theory of Mr Fox [on the formation of veins], I forgot to notice that Sir Charles Lemon had apprised the meeting [at Redruth Institution] that it was Mr Fox's intention to publish his Theory, together with a long series of questions relating thereto (which he also read at the meeting), in the forthcoming volume of the Transactions of the Royal Geological Society. This resolution will no doubt be hailed with pleasure by very many; but seeing that comparatively speaking a small minority only of the practical miners become possessed of the transactions of the Geological Society, perhaps I may be able to suggest the propriety of publishing the Theory in another form. - If instead of being confined to the pages of the Geological Transactions it were published separately in the form of a cheap pamphlet...

But not all in Cornwall were so enthusiastic. Less than a month after Fox had read his paper to the Redruth Institution, W. J. Henwood gave a paper with a similar title, 'On the phen-
This was exceptionally critical of Fox's ideas, and was printed in the *West Briton* on 9th December 1836, and in January 1837 in the *Edinburgh New Philosophical Journal*. The account, which was written as a report of the proceedings, began with an explanation of why Henwood should have chosen this subject for his talk. It implied that he had begun the study of veins before Fox:

...the question of the origin of veins, had recently been taken up by Mr Fox, and having deservedly attracted much attention, it had been thought advisable [by Henwood] to follow it up while the impression remained. Mr Henwood had, for several years, been engaged on the subject...

He then went on to explain how he disagreed with the ideas of Werner, Hutton, Sedgwick and Fox on the origin of veins, arguing instead that the most probable explanation of their formation was that they were contemporaneous with the rocks in which they were formed. The section of his paper which caused most offence however was that in which he indirectly accused Fox of plagiarism:

The idea of electric filling up [of veins] was first given by Professor Sedgwick... The artificial production of crystallized metallic substances from solutions by the electric action of the solutions alone on each other, was first discovered in France by M. Becquerel, as long ago as 1827, and his experiments anticipate nearly all that has been hitherto done in the country... some account of these... discoveries appeared in an English Journal early in 1830...

A translation of a paper by Becquerel, 'The influence of electricity in the formation of certain inorganic bodies', had appeared in the *Edinburgh New Philosophical Journal* in 1829. His main work, *Traité de Électricité*, was published in 1835. Fox was always careful to attribute information which he had obtained from other sources, and to refer to investigations by different authors in his papers.
seems unlikely that he would not have given credit to Becquerel, had he been aware of his work; further comments on this point will be made below.

The most cogent part of Henwood's argument against Fox's theory was given in the summary of his paper: 137

...we have no experimental knowledge that rocks now are, or ever were, in opposite electrical states; our real knowledge extending to the existence of electric currents in the present metalliferous contents of veins only.

In 1837, an article by Henwood was printed in the Quarterly Mining Review (having already been published in Annals of Electricity in a shorter form). 138 He set out a table of comparisons of the experiments made by Fox and by A C Becquerel, and argued that his own observations conformed with those of the latter: 139

The discovery of electric currents in the present contents of veins, appears to me to have no necessary connection with the mode of the original deposit [sic]...

In July 1838 a paper by A C Becquerel, translated by Henwood, was published in the Edinburgh New Philosophical Journal. 140 Becquerel made a number of points about Fox's experiments: 141

All the substances that form part of metalliferous veins are far from possessing the conducting powers necessary to allow the passage of currents transmitted by the metallic portions... Mr Fox assures us, that he has discovered that the beds of clay-slate (killas) in Cornwall appear to possess the property of conducting free electricity in a slight degree, but only in the direction of their cleavage. This effect can be attributable only to the water interposed.

He also however criticised Henwood's methods: 142

We are not aware whether Messrs Fox and Henwood have, in their experiments, sufficiently guarded against all the causes of error which present themselves when we seek for the existence of electro-chemical currents by means of the multiplier.
In order to shew in what manner electric currents have acted, and are acting, on metalliferous deposits, some persons have recently supposed that the veins have been filled by the action of electric currents; but it is only necessary to be acquainted with the manner in which they are filled, to reject such a theory.

Robert Hunt carried out some experiments with J A Phillips (of Cornwall) while in Falmouth, where he was working as secretary of the RCPS, and came to the conclusion that electrical currents could only be detected in vein materials which were undergoing chemical decomposition. Writing in 1887, Hunt commented on Henwood's accusations against Fox:

Certainly Mr Fox commenced his experiments with weak electrical currents without any information of what M. Becquerel had done, and it was only when he had established certain facts that he became acquainted with the results obtained by the French philosopher.

It is probable that Hunt had obtained this information from Fox himself, for he had been employed by the RCPS as secretary from 1840 to 1845. Hunt was also critical of Henwood's own work:

...we feel very reluctantly compelled to arrive at the following conclusions: In the first place, Mr Henwood was not sufficiently acquainted with electrical science to carry out with accuracy a series of delicate observations on electricity. In the second place, the peculiar characteristics of his mind were such as to operate against his making satisfactory deductions from his observations.

Henwood had also given an account of his own ideas about the origin of mineral veins to the BAAS at Liverpool in 1837, where they met with little agreement. An anonymous correspondent to the West Briton, writing about Henwood's reception at the BAAS, said:

Henwood has very much distinguished himself; he stands high in the estimation of men of science, for his indefatigable industry and research, and of course as a Cornishman, I was delighted with his success. He read several papers of interest, but I cannot say that his theory of the metalli-
ferous veins being contemporaneous with the strata in which they occur, met with much approbation;...

A month later the disagreement between Henwood and Fox was continued when both were present at the Annual Meeting of the RGSC. Fox had read a paper in which he made some remarks about temperatures in mines. The West Briton newspaper recorded that:

Mr Henwood said the facts were correct, but the inferences were inaccurate; and this led to a brief but animated discussion in which Mr Fox asserted that the heat in mines is carried upwards by currents of water, ascending from the interior, and Mr Henwood denying it,...

In 1841, Henwood was again apparently critical of Fox at an Annual Meeting of the RGSC:

Mr Henwood said... the subject of chemical changes induced in minerals by electric agency... has never been brought under the notice of this society, and as an attempt of mine to put my own views before another society some years ago was most uncourteously suppressed, I will take... this opportunity of my last appearance among you to point out the present position of the question...

A longer report in the Penzance Gazette of this same meeting gave further detail of Henwood's criticism of Fox's methodology:

...not that he [Henwood] doubted but that some currents existed in the veins and lodes, but the results obtained thus far required revision to free them from these sources of very possible error.

Although the reports of meetings of the RGSC were very guarded, there is little doubt that the disagreement between Fox and Henwood had become so bitter that the society felt it should intervene. The minutes of a Council meeting, held in October 1841, shortly after the Annual Meeting, stated that:
It was resolved
...That the communications made to us by Mr Fox and Mr Henwood on the points of difference between them be reported to a meeting of the Council to be held at the earliest period when the President can be present.

The next Council meeting was not held until January 1842, probably having been delayed while the President, Sir Charles Lemon, was engaged in parliamentary duties in London. The minutes of this meeting were carefully circumspect: 152

Mr Carne then announced that he had that morning received a parcel from Mr Fox, which was produced to the meeting unopened. It was found to contain besides one or two books of reference, a paper from Mr Fox relative to the points of difference between that gentleman and Mr Henwood.

Mr Fox's statement having been read and Mr Henwood having replied to the points respecting himself personally and stated that although the time when he received the notice of the meeting had allowed him such a short period, he was quite ready to enter verbally upon the whole subject, the Council expressed a wish, in order that his statement might have their more attentive consideration, that he would take the trouble to reduce the whole to writing.

A letter from Lemon to Fox about the same meeting was much more frank: 153

Our meeting at the Geol'y produced nothing satisfactory — Your Paper was read; and Henwood produced in justification of himself, a letter of yours dated June 1835, in which you say you have had Becquerel ab't a month but have not had time to read it. Is it possible that the man altered the date? He then shewed a letter from Becquerel in which he says that your experiment was much the same as his own. This is a casual expression which proves nothing, unless the letter to which it is an answer is given also.

Henwood then proceeded to prove that your theory of veins was not original; but as this matter was in no way before us, Mr Tremenheere stopped him, and I requested him to confine himself to his reply to your statement. He then flew at us all, and was most offensive. Joseph Carne did not escape; whom he told that he wanted to entrap him into divulging a part of his case and then refusing to hear the whole. It was impossible to pacify him; and so we prepared the enclosed Resolution.

The resolution referred to in the last sentence of Lemon's letter was that made in the final paragraph of the previous extract. It is not certain whether any further meeting was
held, or what outcome there might have been. There was no relevant entry in the RGSC Minute Book, but on the page following the minutes for the 27th January, the heading, "Meeting of the Council", was followed by a blank sheet. Henwood had resigned his post of secretary to the RGSC at the Annual Meeting in October 1841, because of "private circumstances", but it is not clear whether this had anything to do with the episodes described above. 154

When Volume V of the RGSC Transactions was eventually published in 1843, it was devoted solely to material written by Henwood. A paper 'On the electric currents observed in rocks and veins' was appended to the main survey of mines. 155 In this paper, Henwood was careful not to theorise, giving only the data from his many experiments. Whether he had been warned to avoid further antagonism towards Fox is not known, but he wrote: 156

> Throughout this volume it had been my constant aim to present descriptions and arrangements of the facts which have come under my notice; and to avoid speculation on their causes. I do not intend to depart from this rule in the present instance,...

Throughout the nineteenth century complimentary comments about Fox's theory continued to be included in works which dealt with Cornish mining and similar topics. 157 But research into the origins of mineral veins began to be directed elsewhere, 158 and his work on their electrical origin was never taken up by others. It could be argued that his descriptions of the deposition of vein materials by hydrothermal fluids, and of the progressive enlargement of fissures, which at the
time seem to have received less attention than his electrical experiments, were of more lasting value.

6.5 W J Henwood and the RGSC survey of mines

In the 1830's the RGSC began to hold great store by its promised survey of mines, which was being undertaken by W J Henwood. However the origins of this project are uncertain. In a paper for the Geological Society of London, published in Volume II of the London society's Transactions in 1814, William Phillips described some observations of mineral veins he had made in Cornwall in 1800, but stated that his own work was of limited value, because:159

...the ascertaining of the local and relative situation of mines, though of unquestionable interest to the geologist, can only be regarded as a link in the chain of inquiry. In order to render its value complete, it should be accompanied by a memoir, or rather a comprehensive history of each mine and its connection with those immediately contiguous to it on the same veins. But this could only be attained by years of unceasing and laborious inquiry on the spot.

Whether this recommendation was the motive for the survey is not known. There was however a similarity, which may not be coincidental, between some of the headings used by Phillips to describe veins in his paper, and those proposed by Henwood for his own work, which he listed in a letter to John Hawkins in 1830:160

The phenomena of veins are arranged [in the report] in a tabular form under the heads of "direction" "dip" "size", "contents" "the intersection of veins by one another", also "the dip" of "cleavage of slate" "appearance of granite" "and phenomena attending its contact with slate"...

Phillips had used as headings in his descriptive account: "Direction and Length of Veins, Underlie [dip], Depth of Veins, Width of Veins, Denominations of Metalliferous Veins,
Discovery of Veins, Contents of East and West or Metalliferous Veins", etc.\textsuperscript{161} Henwood had been made a Fellow of the Geological Society of London in 1828,\textsuperscript{162} so it is likely that he would have had access to its Transactions, and would have read Phillips' paper.

John Hawkins' paper on the 'Queries' which he had sent to miners, published in 1818, in Volume I of the RGSC Transactions, may also been an inspiration to Henwood (an extract from Hawkins' explanation of these 'Queries' is quoted on page 194).\textsuperscript{163} As will be seen, Henwood corresponded regularly with Hawkins about his survey in the 1830's.

Information about Henwood's early years is scanty; it is known that from 1822 until 1827 he was a clerk at the Perran Wharf iron works near Falmouth owned by the Fox family, and that his father had been employed there before him.\textsuperscript{164} He is said to have come from a Cornish mining family, which had lost money through speculation in mines.\textsuperscript{165} He was noticed by members of the Fox family at an early age, and was encouraged by them to study geology and associated subjects. An obituary of Charles Fox, in the RGSC Annual Report for 1878, included the following information:\textsuperscript{166}

\ldots it is interesting to know that it was Charles Fox who was chiefly instrumental in starting our late eminent member, Mr Jory Henwood, on his scientific work. Finding him an industrious young clerk in his office, Mr Fox used to invite him to his house frequently to study electricity and chemistry with an invalid brother-in-law, and he afterwards united with Mr Robert Were Fox in arranging for that inspection of mines which led to the publication of your fifth volume.

In 1825, at the age of only 20, Henwood read his first paper
to the RGSC 'On metalliferous veins'.\textsuperscript{167} This paper was not published, and no further details of it remain. In the following year he was elected an ordinary member of the society, an exceptional honour for a man of his background; perhaps a sign of the respect with which the Fox family was regarded.

There is little information about Henwood's suitability to undertake his survey. In 1830, John Hawkins had offered to sponsor him, in order to allow him to study at Freiberg for a period. In December 1830 Joseph Carne wrote to Hawkins, at his home in Sussex:\textsuperscript{168}

\begin{quote}
...when I had the pleasure of seeing you here [in Penzance], you alluded to the situation of Mr Henwood, and expressed a wish that he might be enabled to go to Freyberg [sic] for a little time.
\end{quote}

A few days later Henwood wrote to Hawkins, indicating a willingness to go to Freiberg, but saying that as he had already begun his work on the survey, he wished to complete this first:\textsuperscript{169}

\begin{quote}
I should gladly embrace the plan you do so kindly propose for obtaining a knowledge of the German system of Mining Dressing &c and from the very little I know of them from short interviews with German miners I am convinced in the latter department we are very far behind them.

...I am now so firmly pledged to the Noblemen and Gentlemen of the neighbourhood to carry the investigation which you are so kindly disposed to support, into effect, that I am bound to endeavour to complete it.
\end{quote}

There are no further letters on this subject, and there is no evidence to suggest that Henwood ever went to Freiberg.

Henwood appears to have begun his survey on his own initiative. It is possible that he devised the scheme in order to make money for himself, as in 1830, in a letter to John Hawkins, he wrote that apart from his work on the survey, he was
"not being otherwise employed".\textsuperscript{170} It is not known why he should have left the employment of the Foxes.

There is some uncertainty about exactly when Henwood began work on the survey. An obituary in the RGSC \textit{Annual Report} for 1875 stated that he commenced in 1826; this information was based on a letter from Anna Maria Fox, who had written on behalf of her father, R W Fox.\textsuperscript{171} In 1843, in the introduction to his main paper in Volume V of the RGSC \textit{Transactions}, 'On the metalliferous deposits of Cornwall and Devon', Henwood wrote:\textsuperscript{172}

\begin{quote}
...For two or three of the earlier years my progress was but slow; but in 1828, at the desire of Messrs. Robert Were Fox and Charles Fox, the investigations were prosecuted with greater activity;...
\end{quote}

According to Henwood in 1830, the Fox brothers each gave him £10 towards the cost.\textsuperscript{173} In a letter to Richard Taylor, editor of the \textit{Philosophical Magazine}, published in that journal in 1831, Henwood explained:\textsuperscript{174}

\begin{quote}
In the year 1829, at the desire of R. W. Fox Esq. of Falmouth, and C Fox Esq. of this place [Perran Warf], who also defrayed the expenses incidental thereon, I made an examination of the leading geological features of several of the mines of Cornwall;...
\end{quote}

A letter from Fox to Davies Gilbert in 1831 included the information that: "Mr J Henwood has I believe commenced his geological investigation of mines beginning with the parish of St Just".\textsuperscript{175}

The two extracts quoted immediately above imply that the survey was initially begun on a small scale, with the financial support of R W and Charles Fox. In about 1830, the project was expanded to include all the mines of Cornwall. It
appears from the letter quoted below, that this decision was made by Henwood himself. Carne wrote to John Hawkins in December 1830: 176

[Henwood] has lately written to me expressing his wish to undertake a general examination of all the Mines in Cornwall, to include not only all the particulars respecting the different kinds of veins, but also their electro-magnetic properties, the magnetic intensity at different depths, the temperature of the mines, &c, and to attend to any suggestions which may be made by the Geological Society here... He has spoken to Lord De Dunstanville, Sir Chas. Lemon, the Messrs Fox &c, who have entered into his views, and subscribed towards his projected undertaking.

There is no record in the RGSC minutes, which are very defective for this period (see below), to indicate when the survey became a formal subject for support by the society. Henwood informed John Hawkins in 1830 that: 177

...it is the intention of the Council to honour [the results of my recent observations] with a place in the forthcoming volume of Transactions... I am sanguine that this survey will not be entirely without practical utility, and the results of my examinations, I will of course place at the disposal of the Gentlemen to whose goodness I may be indebted for the means of effecting them - possibly they may deem the Penzance Society no unsuitable repository for them.

In June 1831 Joseph Carne, at that time editor of the RGSC Transactions, wrote to Hawkins: 178

I think there is no other objection to your plan of printing Mr Henwood's researches by themselves, as a fifth volume, than the delay which such a measure will occasion to the fourth, for having calculated not less than a hundred pages for his first paper,... I fear there is little prospect of completing the volume by our next meeting...

The most complete description of Henwood's intentions were given in a news item in the Annual Report of the RIC for 1831: 179

Mr W J Henwood... [has] proposed to undertake a most extensive survey of the Mines of the County, and to make a particular examination of the various lodes, and of the Magnetic
and other phenomena connected with them, a survey which could not fail to accumulate and concentrate a vast body of facts tending to illustrate this obscure branch of natural philosophy...

Henwood was able to obtain financial support for the extended survey, for he listed donations totalling over £202 in his main paper. This included ten pounds from the RGSC, the same amount from the RIC, and five pounds from the Yorkshire Philosophical Society, as well as sums from individuals, most of whom were Cornish. In 1842, Henwood estimated that the survey had cost him "nearly £1000". He did not state whether the additional costs had been met by himself, or by others. The RGSC 'Treasurer's Reports' gave information about the cost of printing Volume V, a total of about £50, but there were no other expenses listed which were directly attributable to the survey.

In 1830 it was thought that the survey would take "something less than twelve months" to finish. In October 1831, Henwood wrote to Hawkins implying that it was nearly complete, for he was considering what he could do afterwards. He also included information about his progress: "I have now about finished all the mines west of Redruth and for the present have those west of St Agnes in hand". In December 1832 however Joseph Carne wrote to Hawkins:

Mr Henwood has not yet finished his survey of the Mines; when it is completed an arrangement will speedily be made for the publication of a 5th volume...

In December 1833 Henwood wrote to Hawkins that "early in the spring, all my investigations will be completed".
At some stage it was decided to add material on the mines of Devon to the survey. A report of Henwood's speech to the Penzance Institute in 1836 included the information that he had "inspected the mines in this and the adjoining county". The first recorded paper by Henwood for the RGSC which included details of mines in Devon was read in 1830. In 1833, Henwood wrote to tell Hawkins that he had met De La Beche at Tavistock, where the surveyor was mapping the mining areas, but added that "De la Beche would not be prevailed on, to go underground, saying that he would not enter on my field." It is not clear from the letter whether Henwood was engaged on his own survey during his visit to Tavistock; he may have been there on business for the Duchy of Cornwall, for whom he was working at the time (see below).

In 1834 the Council of the RGSC was able to report that: "Mr Henwood has at length terminated his survey of the mines... and he has promised to complete his paper on the Metalliferous Veins of Cornwall against the next anniversary". The paper did not appear in the following year, and similar reports were made in the following three years. From 1837, Henwood was the Secretary of the RGSC, and the 'Reports of the Council' would have been drafted by him. In 1838, the following paragraph was included in the RGSC Annual Report:

Unforeseen circumstances, chiefly on the part of the printer, have delayed the appearance of the fifth volume of the Society's Transactions: but a considerable portion of it, embracing a large part of Mr Henwood's Memoir on the Mines of the County, on which he has been more or less occupied for twelve years past, is now on the table; and, the surveys being all completed, it will be published in the early part of the ensuing year.

In 1839 the Council had to report:
...the Council again have to express their regret that the Fifth Volume of the Society's Transactions, which was promised at the last meeting, had not yet been completed. The delay is principally owing to the Editor, and to circumstances over which he has no control...

The editor of this volume was Henwood himself. A resolution which was passed at the Annual Meeting of the RGSC in the same year suggests that members were becoming impatient of the delays in publication:

> It was resolved... That the Editor of the Society's Transactions be directed to proceed with all practical dispatch with the printing of them, be authorized to agree for the preparation of the plates and for the charges of the Printer.

In 1842, Henwood was at last able to demonstrate some proof pages of his memoir at the annual meeting of the RGSC, but it was not until November 1843 that the society was able to announce that Volume V was "ready for delivery to members."

That Henwood's survey should have taken so long must be due in part to the scale of the task. He claimed to have visited "more than two hundred mines, and travelled underground nearly, if not quite, two thousand miles". However the underground work was reported to have been finished in 1834, and the hidden message in the extracts from Annual Reports quoted above suggests that it was writing the papers, and compiling the tables and diagrams, that were the main causes of subsequent delays.

The volume contained five papers, all by Henwood; the greatest part, consisting of 386 pages, contained the details of the survey of the mines of Devon and Cornwall. There were also papers on subterranean temperatures, 'On the quantities of water which enter the Cornish mines', 'On the electric
currents observed in rocks and veins' and 'Statistical notices of the mines in Cornwall and Devon'. Twelve plates and one hundred and thirteen tables accompanied the main paper. Most of the plates showed plans or sections of the lodes in selected mines. Ninety eight of the tables used a common form, with the following headings:

- Name and direction of vein
- Depth/fms
- Dip
- Size [ie. width]
- Appearance and composition [of ore and gangue minerals]
- Appearance of rock

Additional columns were used where necessary to describe "cross courses", "heaves" and tributary lodes. The remainder of the tables summarised information from the earlier part of the paper. There were also comprehensive tables associated with the subsidiary papers.

Some of the delay in finishing the survey must be the result of Henwood's involvement in other work. Between 1832 and 1841 he held various appointments with the Duchy of Cornwall. He was appointed as Deputy Assay Master to the Duchy in 1832, and in 1833, was made one of the four "Surveyors of Tin Blowing"; in 1836 he became Assay Master of Tin for Devon and Cornwall. The post of Deputy Assay Master was a sinecure, and it is likely that that of Surveyor of Blowing Houses was similar. Henwood obtained the first post on the recommendations of Davies Gilbert, Sir Charles Lemon, "and other scientific and very influential persons in the County of Cornwall". Henwood wrote to Hawkins explaining that he had been recommended to a post with the Duchy, in order to find him an income which would allow him time to complete his survey, and
to assist the scientific societies of Cornwall in other unspecified ways. 202

Henwood also undertook other scientific studies in Cornwall and elsewhere, which must have detracted from the time he spent on the survey. In 1833 he made a detailed investigation of terrestrial magnetism, which he described in a letter to the Duchy of Cornwall Office: 203

By means of 7000 observations made at each of three stations, within the last three months, I think I have discovered that the greatest force of terrestrial magnetism resides at the mean surface of the earth - And that whether we ascend, hills or descend into Mines, - the force as we recede from the surface diminishes. I have ascended no more than 700 feet - but I have descended and continued several times 24 hours each time at the depth of 1260 feet.

He read a paper about this work to the RGSC in 1833 but it was not published. 204 In 1841, he spent "three or four months" in Canada and the United States, investigating the geology of New Brunswick for "some gentlemen with whom he had the honour of being acquainted". 205

There were few reviews of Volume V when it finally appeared. The two Truro newspapers ignored it, as did the Penzance Gazette. There was no comment in the Philosophical Magazine, nor in the Mining Journal, nor in the Proceedings of the Geological Society of London. This apparent lack of interest may have been because much of Henwood's work had already been made public, at meetings of the RGSC, the British Association, etc, and in some journals. He had delivered papers to the RGSC on mineral veins in almost every year between 1830 and 1840 (see Appendix 9). The bulk of his memoir was taken up with details of individual mines in Cornwall and Devon, which would have
interested only a minority of people. The cost of the volume was also comparatively high, 30/- for the public, and 25/- for members of the RGSC. 206

At a rather later date, in 1859, Henwood's methods were criticised by a Cornish mines captain: 207

[Henwood] took only the general bearing of the lode from one end of the mine to the other, overlooking the variations between the productive and unproductive parts. By this omission he not only lost a fine opportunity of accumulating many important facts, but the whole subject of bearings by his mode of statement has a direct tendency to mislead.

Henwood did not make any contribution to geological ideas, for he deliberately abstained from theorising. He wrote: 208

In a memoir so strictly practical, theoretical speculations would have been misplaced:-- from such, therefore, however inviting, and even from the use of hypothetical language, I have carefully abstained. The only instance in which I have departed from the rule I had thus prescribed myself, is the enquiry, whether the results of any uniform and simple motions of the severed portions of lodes will afford a sure and unerring guidance to the discovery of the parts which are heaved. This, if true, would have been so valuable and important to the miner, that I felt such an exception would be excused.

This exception, his refusal to concede that "the vein intersected is older than that which intersects it", 209 Henwood had already presented at meetings of the RGSC in papers in 1834 and 1836 on slickensides (see Appendix 9). Only the titles of these papers still exist, but that of the first, 'An examination of the Cornish slickensides, showing evidence that they cannot be referred to mechanical origin' makes clear the argument that he was trying to pursue. He had also given a paper to the Geological Society of London in 1833 'On some intersections of mineral veins' in which it was reported that he tried to "combat the received opinion that all inter-
ruptions or intersections in mineral veins are the effects of disturbances". 210 He persisted with a similar argument in 1837 at the BAAS meeting at Liverpool. 211 These ideas were therefore not new when Henwood included them in his memoir; they also went against the trend of contemporary opinion. The Rev Adam Sedgwick was especially critical of his ideas. 212

Henwood was also capable of distorting facts when he wanted to present a favourable image of himself. For example in his memoir, he claimed to have found fossils (corallines) in rocks near St Columb in 1829. 213 He had however written to Hawkins in 1833 suggesting that he had never found any fossil material, and excused this omission with the following justification: "For my own exculpation I believe I need only say that you know the veins have exclusively attracted my notice". 214

The dispute between Henwood and Fox, although handled discreetly in public, must have been known about widely, and because of this Henwood may have lost much of the respect which he should otherwise have received for his work. It is likely that Fox, respected both in Cornwall and nationally for his scientific work, as well as for his conduct of his business affairs, would have had the greater amount of public sympathy. There may have also been some suspicion that Henwood was trying to usurp the position of the man who had initially given him help in his scientific studies, for Henwood's own work frequently mirrored that of Fox. Fox had begun his studies of high temperatures and electricity in mines, and of magnetism, before Henwood had embarked on his
In the summer of 1843, even before Volume V of the Transactions was published, Henwood left England for Brazil, to complete some work for the Imperial Brazilian Mining Company.\textsuperscript{215} It was reported by local newspapers that he intended to stay for about ten months,\textsuperscript{216} but he remained abroad for ten years, after he had been appointed as principal resident manager of the Gongo Soco Gold Mines in 1844.\textsuperscript{217} During those years, he forwarded a series of papers on mines in South America, India, Ireland, etc, to the RGSC, and in 1871, two large books of his work were published as Volume VIII (Parts 1 and 2) of the RGSC Transactions. In later years, the mines survey of Cornwall and Devon became respected for what it was, a comprehensive documentary record of the mines in the 1830's.

6.6 The RGSC and the origin of mineral veins after 1840

After about 1840, members of the RGSC started to take greater interest in the subjects which also concerned the Geological Society of London, fossils and stratigraphy. This was mainly prompted by the discoveries of abundant Cornish fossil material in about 1836, by Charles Peach and De La Beche. (Peach was a riding officer for the Customs, who had observed and collected fossils around the south coast of Cornwall.\textsuperscript{218}) The study of minerals veins was all but abandoned in favour of the more attractive pursuit of fossil collecting. The efforts made by the society to assist in locating new deposits of stream tin had not been successful, for the quantities of
grain tin being produced began to fall in the 1830's. This may have contributed to a lack of confidence in the abilities of the RGSC to assist the mining industry.

There may be an inverse correlation between the number of papers given to the RGSC on mining subjects, and the prices of tin and copper, although this is difficult to prove statistically. Figure 19 shows the trends of three curves, representing the numbers of papers read, and the production of copper and tin. (See also Appendix 12.) There does appear to be an increase of interest in mining in years when prices fell, and a converse lack of interest when prices were rising. In 1835-6 there was a short-lived boom in tin mining and some old mines were reopened. In 1838 tin coinage duties were abolished; these had in effect been a tax of about 8-10% on Cornish tin, from which foreign production was exempt. For a short time home production benefited, but after 1843 import duties on foreign tin were abolished, and imports from Malaya became increasingly important. Copper mining was also prosperous in the 1830's, with new discoveries being made in the Gwennap and Caradon Hill areas. There was a recession in 1837, and the important Dolcoath mine was partially stopped. In the 1840's production rose again, especially in the area around Illogan.

In 1843 Sir Charles Lemon urged that Joseph Carne should renew his studies of the Cornish granites:

I hope Mr Carne will pardon me if I bring to his mind that he has heretofore observed much, and written well on this branch of Geology; and that he would undertake an essential service to the science which he cultivates if he would again take up the hammer which has been so long on his shelf.
In the earlier years of the society Carne had been a major contributor of papers on veins. Why he should later have neglected the study of geology is not known; after 1834 he wrote fewer papers for the society, and in some years his only contribution had been the presentation of the annual tin statistics. It is possible that he was becoming increasingly involved in the family banking business, for his father had died in 1836, his only son having already died of consumption in 1832 at the age of 23. He had also been elected as President of the Penzance Library in 1834, and was said to have spent much of his time in purchasing, cataloguing and arranging their collection of books.

In 1859 a new President, Augustus Smith, was to express his regret that the researches into Cornish metalliferous deposits by Henwood had not been followed up by the society.
NOTES AND REFERENCES

1. Taylor (1834), (4).
2. Ibid.
3. 'Anniversary Address of the President' RGSC Annual Report 1890, pp.183-195, (187). Smyth had been mining geologist to the Geological Survey, and later a lecturer in mining and mineralogy at the Royal School of Mines.
4. Minutes of initial meeting, 11th February 1814, RGSC Minute Book No.1.
5. Ibid.
6. Davy (1818B), (38-9).
7. Carne (1822A), (50).
8. Taylor (1834), (2).
9. Buckland (1836), (vii).
11. DNB.
12. Hawkins (1822A), (5).
13. Taylor (1834).
15. Attempts to trace French influences on the foundation or early years of the RGSC have been unsuccessful.
17. John Woodward (1723), (208).
18. Borlase (1758), (143-4).
19. Ibid. (158-9).
20. Ibid. (184).
22. Ibid. (4).
23. Borlase (xiii-xvi); Pryce (pages not numbered).
24. Phillips (1814); Taylor (1814).
46. Ibid. (60, 65).
47. Ibid. (65).
48. Ibid. (123).
49. Ibid. (124).
50. Hawkins (1818B), (245).
51. Taylor (1834), (1).

52. De la Beche (1839), (355). The reference to Fox was to a statement in R W Fox (1836A), (1).

53. Hawkins (1822D & B). In the volume both papers were described as having been read in October 1820; however in the Minute Book No.1, 'On the intersection...' was recorded as having been read on 21st September 1819. Therefore although this paper was printed after 'On the phenomena...' in the Transactions, it seems more logical to discuss it first.

54. Hawkins (1822D), (238-40).
55. Hawkins (1822B), (225).
56. Hawkins (1822B).
57. R W Fox (1822A & B); Forbes (1822A); M P Moyle (1822).
58. T F Barham (1827); R W Fox (1827).
59. John Davy (1836), 2, (140-1).
60. Hunt (1887), (375-6).
61. Henwood (1843B), (Table V, 404).
62. R W Fox (1827), (325).

64. Ibid. (580).

65. Report of the third meeting of the British Association for the Advancement of Science; held at Cambridge in 1833, London, 1834, (12).

66. Report of the seventh meeting of the British Association for the Advancement of Science; held at Liverpool in September 1837, VI, London, 1838, (74).
67. Hawkins (1818A), (201).
68. RGSC Annual Report 1823.
69. Carne (1822B), (333).


71. Henwood (1832).

72. Colenso (1832); Carne (1832A); Carne (1832B).

73. RGSC Annual Report 1835.

74. Henwood (1832), (66-7).

75. Carne (1832A), (55).

76. Carne (1832B), (96).

77. Ibid. (102).

78. Humphry Davy (1812), (175-6).

79. Quoted in Siegfried and Dott (1980), (xxxix), (Lecture I (1811)).

80. Collins (1878).

81. Ibid. (3).

82. R W Fox (1831A), (94-9).

83. R W Fox (1822B), (447).

84. R W Fox (1836A), (101-2).

85. R W Fox (1829), (17).

86. Ibid. (18).

87. Collins (1878), (15).

88. Report of Royal Cornwall Polytechnic Society, 1836, Plate VI, Fig. 22.

89. R W Fox (1830). The references to the other journals were given in Collins (1878), (14).

90. R W Fox (1830), (406-7).

91. Ibid. (400).

92. Ibid. (402).

93. R W Fox (1832D), (25-6).

94. Fox produced seven papers for the RGSC between 1819 and 1830. Between 1834 and 1840, he gave only two.
95. Collins (1878), (22).

96. Ibid. (22).

97. Report of the first and second meetings of the British Association for the Advancement of Science; At York in 1831, and at Oxford in 1832: including its proceedings, recommendations and Transactions, London, 1833, (52).

98. Report of the third meeting of the British Association for the Advancement of Science; held at Cambridge in 1833, London, 1834, (474).


100. R W Fox (1837B), (133).

101. R W Fox (1832A), (123-5).

102. Whittaker (1962), (90). Fox referred to Seebeck in 1832, in R W Fox (1832C), (313).

103. Whittaker (1962), (88-9).

104. R W Fox (1832C), (124-5).

105. Whittaker (1962), (175).

106. R W Fox (1836B), (406).


108. Fox's ideas were read to the Geological Society of London in April 1836; see a letter to J S Enys from Davies Gilbert, quoted in Collins (1878), (39). The BAAS meeting was at Bristol in August; see Report of the sixth meeting of the BAAS for a summary of Fox's paper (81-2). His presentation to the RGSC was described in the West Briton for 9th September 1836.

109. R W Fox (1836A).

110. Ibid. (81).

111. Ibid. (110-3).

112. Collins (1878), (41).

113. R W Fox (1829), (17).

114. R W Fox (1836A), (102).

115. Bauer (1910), (207).

116. Letter quoted in Collins (1878), (15).

117. Buckland (1836), (552, footnote).
118. Taylor (1834).
119. Ibid. (18).
120. Sedgwick (1835A), (185).
122. Pattinson (1840), (26).
124. Monk (1972), (30).
125. De la Beche (1839), (349-394).
126. Ibid. (379).
127. Ibid. (381).
128. West Briton 9th September 1836.
129. Royal Cornwall Gazette 18th November 1836.
130. West Briton 2nd December 1836.
131. Henwood (1837B).
132. Ibid. (152).
133. Ibid. (164-8).
134. Ibid. (168).
136. See for example the tribute to Joel Lean in R W Fox (1822A), (19).
137. Henwood (1837B), (170).
138. Henwood (1837A).
139. Henwood (1837A), (225-9).
140. Becquerel (1838).
141. Ibid. (169).
142. Ibid. (171).
144. Hunt (1887), (389).
145. Pearson (1976), (23).
146. Hunt (1887), (394).

147. West Briton 22nd September 1837.

148. West Briton 20th October 1837. There were no minutes of this meeting in the RGSC documents.

149. West Briton 1st October 1841. There was no record of the meeting in the RGSC documents. The reference to the suppression of his views may relate to the RCPS, for at a Special Meeting of the Committee of that Institution, a resolution was made "That the Secretaries be requested to inform Mr Henwood that the topics generally contained there in have previously been discussed by the Committee and are still under consideration". (Minute Book of RCPS 1835-1839 (82)). An alternative possibility was the withholding of one of his papers by the Geological Society of London for a year before publication (1831), which he described in his paper to the Penzance Institution (Henwood (1837A), (162)).

150. Penzance Gazette 29th September 1841.

151. Minutes of Council Meeting 27th October 1841, RGSC Minute Book No.1.

152. Minutes of Council Meeting 27th January 1842, RGSC Minute Book No.1.


154. Royal Cornwall Gazette 1st October 1841.

155. Henwood (1843D).

156. Ibid. (458*-9*). Note that pages 453-460 appeared twice in the volume, the second set differentiated by "**".

157. See for example Leifchild (1859).

158. A book by a mining engineer, Evan Hopkins, who had travelled in South America, Ireland etc, appears to have been derived in part from Fox's ideas; the author however paid more attention to studies of magnetic forces in his theory of the formation of metallic ore deposits: Hopkins (1844).

159. Phillips (1814), (112).


161. Phillips (1818), (113-140).

162. DNB.

163. Hawkins (1818B).

164. DNB.
165. Ibid.

166. 'President's Address', RGSC Annual Report for 1878, (xiii).

167. RGSC Annual Report 1825.

168. Carne to Hawkins, 4th November 1830, WSRO (H) 2, Pt.7/920.

169. Henwood to Hawkins, 10th December 1830, WSRO (H) 2, Pt.7/921.

170. Henwood to Hawkins 25th November 1830, WSRO (H) 2, Pt.7/917.

171. RGSC Annual Report 1875 (x).

172. Henwood (1843A), (2).

173. Henwood to Hawkins 25th November 1830, WSRO (H) 2, Pt.7/917.

174. Henwood (1831), (358).

175. R W Fox to Davies Gilbert, 3rd Month 1831, Royal Society, Fox Letters 710/37.

176. Carne to Hawkins, 4th December 1830, WSRO (H) 2, Pt.7/920.

177. Henwood to Hawkins, 25th November 1830, WSRO (H) 2, Pt.7/917.

178. Carne to Hawkins, 30th June 1831, WSRO (H) 2, Pt.7/935.


180. Henwood (1843A), (3).

181. Royal Cornwall Gazette 21st October 1842.

182. 'Treasurer's Reports' in RGSC Annual Reports, 1840-2.

183. Henwood to Hawkins, 10th December 1830, WSRO (H) 2, Pt.7/921.

184. Henwood to Hawkins, 8th October 1831, WSRO (H) 2, Pt.7/943.

185. Carne to Hawkins, 19th December 1832, WSRO (H) 2, Pt.7/963.

186. Henwood to Hawkins, 21st December 1833, WSRO (H) 2, Pt.8/1024.

187. W J Henwood (1837A), (152).
188. RGSC Annual Report 1830.

189. Henwood to Hawkins, 21st December 1833, WSRO (H) 2, Pt.8/1024.

190. RGSC Annual Report 1834.

191. Ibid. 1835-7.

192. Ibid. 1838.

193. Ibid. 1839.


195. Royal Cornwall Gazette 21st October 1842.

196. Advertisement in Royal Cornwall Gazette 17th November 1843.

197. Henwood (1843A), (386).

198. Duchy of Cornwall Office, Duchy Servants Register.

199. Henwood to Hawkins, 8th October 1831, WSRO (H) 2, Pt.7/943.

200. Ibid.


202. Henwood to Hawkins, 8th October 1831, WSRO (H) 2, Pt.7/943. There were no mentions of this in the records of the RGSC or RIC, the two societies mentioned in the letter to Hawkins.


204. RGSC Annual Report 1833.

205. Royal Cornwall Gazette 16th October 1841.

206. RGSC Annual Report 1843 (23).

207. Charles Thomas (1859), (26).

208. Henwood (1843A), (384).

209. Ibid. (382).

210. Henwood (1833), (148).

212. Sedgwick (1835B), (484).
213. Henwood (1843A), (157).
214. Henwood to Hawkins, 16th February 1833, WSRO (H) 2, Pt. 8/972.
215. West Briton 14th July 1843.
216. Ibid.
217. Penzance Gazette, 1st May 1844.
218. Ibid.
220. Rowe (1953), (201).
221. Ibid. (197).
222. Ibid. (205-6).
224. Ibid. (74).
225. Ibid. (92).
226. RGSC Annual Report 1843 (17).
227. RGSC Annual Reports 1834-40.
228. Death of Joseph Carne jun, Royal Cornwall Gazette 28th January 1832. Death of William Carne senior Royal Cornwall Gazette 8th July 1836.
230. RGSC Annual Report 1859 (13).