

EXPLORATION

of the

ABERFOYLE MINE AND AREA.

H. CONOLLY,

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SUMMARY OF PROPOSED EXPLORATION.

SINK SPIERS SHAFT to open No.7 level. Opening below 7 will depend on results of 5 and 6 level and of surface drilling and these results should be available before shaft reaches No.7 level.

SURFACE DRILLING.

	No. of holes.	Target numbers	Total drilling footage.	Longest hole.	Remarks.
	2 - 3	T1,2,4,3	2700' - 4900'	2000'	Continuation of the Aberfoyle deposit in depth.
	2 - 4	T7,5,6,8	2300' - 5300'	1500'	Concealed ground around mine.
Total	4 - 7		5000' - 10200'	2000'	costing £5000 - £10,000.

Campaign will open on T1 with hole S1 :-

Target at 1000 S 1464 W - 1125 R.L.

Drilling station " 1000 S 1613 W 00 R.L.^x

Course and length E at 85° down 1200 feet.

No further holes can be sited until S 1 completed.

The scheme of drilling - Targets 1, 2, 4, 3, 7, 5, 6, 8 - is shown on 1" = 100' drilling plan and discussed in report.

OPEN NO.12 VEIN on No.3 level. See 1" = 30' mine prospect plan about 300 S East. Other minor development objectives on upper levels will be given in report. No urgency is attached to any work above No.4 level.

UNDERGROUND DRILLING.

Hole No.	Drilling Station		Course	Length	Remarks.
	Level	Co-ordinates			
U 1.	1	1300S 827W	S73E at 0°	300'	Concealed ground around mine.
U 2.	4	353S 1105W	N35E at 0°	140'	Keel below Eastern Vein.

x Drilling station at R.L.00 means hole will be lined up through this point, the actual site, at the surface R.L., being determined when position is surveyed.

PLANS AND SECTIONS.

Set of mine level plans and sections
showing veins, faults and bedding.

These are to be kept to date

1" = 30'.

Surface plans.

1" = 100'.

Plan Projection showing Aberfoyle deposit,
extent of concealed ground and
drilling planning.

1" = 100'.

Drilling Section 1000 S. Target T1 and Hole S1.

1" = 100'.

Drilling Section of 30° drill hole employed
in planning.

1" = 100'.

Plan Projection showing mine prospects.

1" = 30'.

These plans and sections are at the mine office.
Copies of the 1" = 100' plan projection and two sections
covering drilling planning have been sent to the Melbourne
office.

EXPLORATION OF ABERFOYLE MINE AND AREA.

Puzzling features in the development of the bottom levels determined the Board of Directors to call for a geological examination to advise on further exploration of the mine and area, particularly whether this search should now be directed laterally rather than downwards in depth. This examination has been completed and a letter was sent to the Chairman of the Board on August 7 outlining the underground work and surface drilling recommended so that preparatory steps for this exploration could be undertaken without delay.

The proposals in detail will be given again in this report and they are also summarised in the frontispiece here. To carry the campaign through as designed it remains necessary to place on record the thinking given to this initial planning. Such recording, to meet the issues facing this exploration, means a long and technical report and it must be assumed that the reader knows the mine well and is familiar with the plans and sections prepared.

Exploration planning, like any other planning, must be prepared to meet any contingency and the first stage in this work is therefore the employment of geology as a way of thinking which directs and allows a free mental approach to all conceivable prospects and all conceivable happenings in the way of any projection of an ore-body or structure. There is a compelling need here to keep an open mind accepting nothing except fact. What and where is the target supposing the geological argument to be right must be followed by the same questions supposing that argument to be partly or wholly wrong. This questioning will not appear in a report as very constructive and yet it lays the thinking foundation on which all decisions are built. For it is in the second stage of the work that the loosely held geological picture is collared and translated into a practical, specific, accurately sited and firmly recommended scheme of attack. This is done by an engineer treatment of the problem, employing geometry and common sense, with

the aim of killing as many birds as possible with one stone by locating the tests where there is a maximum overlapping or loading of prospect targets and information. The reason for all this care is to save money and time. Exploration is expensive and risky and the outstanding feature of its control is indeed the need of economy. While the argument builds up on geological ifs and buts exploration, at the last determined by cost, offers as much scope for expert and exact planning as any other job in mining.

The report will be divided under these headings:-

CONCLUSIONS

INTRODUCTION TO THE PROBLEM

THE ABERFOYLE AND 40 FAULTS

EXTENSION OF THE ABERFOYLE DEPOSIT

DOUBTS OF CONTINUED EXTENSION

INFLUENCE OF ROCK FOLDING

PROPOSED EXPLORATION.

CONCLUSIONS.

While the Aberfoyle area is extensively concealed there is evidence that the mine is on one of the major structures of the district which structure is seen underground in the fan-shaped grouping of the tin veins. This fan is tilted irregularly towards the south and it is thought that the deposit will pitch south in and with this structure. The broad view of this tentatively held picture has not lead to any clues pointing to the existence of other near surface deposits in the neighbourhood of the mine and the interest in this environment remains with the chance that anything can happen in concealed ground. Nor does the interpretation promise any important lateral extension of the Aberfoyle deposit although it does look as if the northern end of the vein group has not been fully developed. On the other hand there can be considerable ore reserves ahead of the mine in depth and the downward continuation of the Aberfoyle deposit, even accepting all the uncertainties attached to it, appears to be the substantial and tangible prospect of the area.

The proving of Aberfoyle in depth now is important. The deposit, if it continues with anything like its size above 6 level, will be capable of a much greater production than the present 22,000 tons a year. The opened Nos. 1 to 4 levels measure around 350 to 400 tons per foot of mineable quartz which means production for the mill of about 1,000 tons of quartz and rock from one foot of the veins as they are being worked to-day. It is safe to conclude that the deposit, continuing, could support a production of at least 44,000 tons a year and it is the management's view that this doubling of output could be handled through the existing shaft and mill. With the chance in sight of increased production and increased profit, there is urgent need therefore to show the downward continuation of the deposit in order to step up the development of the mine.

Facing this need there is today uncertainty in regard to how far the known deposit will extend in depth and also in regard to the course this extension will follow. The chance of considerable life ahead of the mine exists because deposits like Aberfoyle are not shallow and surficial but are quite capable of reaching deeply into the earth's crust. Unfortunately this promise does not necessarily or even usually mean that the deposit will extend continuously over its possible range and most mines have to face the risk that, for structural reasons, ore deposition is liable to be intermittent. It is the recognition of structural interference that is the foundation of the belief that there will be a second harvest in hidden deposits beyond and below the worked out mines of Australia.

This *qui vive* of extension versus repetition has come right to the fore at Aberfoyle because there is evidence of structural changes in process which throw doubt on the important extension of any of the known veins. There is nothing at all conclusive about this evidence but the risk cannot possibly be denied. Further, our knowledge of the pitch of the deposit makes any projection uncertain for the fan control has been complicated by an echelon arrangement of the veins and also by the rock folding while, at the end of this thinking, there is the unexplained isolation of the Eastern vein.

Exploration, whether below the mine or in its concealed environment, cannot be economically planned without first a fair idea of the pitch of the known deposit. Obscure as this arrangement may appear to be to-day, a fair idea of the pitch can be, with luck, revealed by one drill hole or at the most two and S1 has been aimed at the critical position T1 to determine the downward extension of the deposit whatever that extension may do. The comprehensive character of the test is possible because crucial information will be gained before S1 is completed, by the development of the bottom levels particularly through the opening up of 6 level southwards.

It is also necessary to resume, without delay, sinking of the Spiers shaft. The deepening of the shaft to open No.7 level

is already warranted by the ore extent on the 6 level while the result of S1 will be obtained before the shaft reaches this objective. This S1 result will show what steps, if any, should be taken to open the deposit below No.7 level and even should it prove necessary to discontinue the sinking of Spiers shaft at 7, this level will be wanted either to step up production or to sustain the operation while another shaft is sunk or search is made for ore repetition.

With the first step concluded, drilling of Aberfoyle in depth can continue with T2, for further information of ore extension, or with T4 and T3 if it proves necessary to search for ore repetition. This stage of the campaign has the following objectives:-

1. To show warranty for an increase of production.
2. To find the location of the deposit below 7 level. It may be too far south for Spiers shaft.
- OR 3. To keep the operation alive, should the known veins bottom below 7 level, by finding where the ore makes again in depth.

With the completion of these two or three holes, attention can be given to the concealed environment of the mine. The absence of any clues pointing to the existence of other deposits does not discourage an economical search of such extensively concealed ground to ensure there are not other ore-bodies hidden, as Aberfoyle nearly was, below the Permo-Carboniferous cover. For the planning, consideration has been given just as carefully to this chance and four well spaced tests - T7, T5, T6 and T8 - have been selected for this search.

The whole campaign has been conservatively planned and there is no question that the expense of up to £10,000 is warranted by the prospects. There is also every confidence that the purpose of the examination - sound economically planned exploration - has been achieved. This does not mean that the work has fully unravelled the geology of the mine; our understanding and view of these ore structures remain limited and uncertain.

In conclusion some mention must be made of the mine's dilution problem because this recommendation to explore is bound

up with the issue. No attempt has been made to go into all the laborious detail attached to dilution studies but a brief enquiry (directed by experience in other mines) was made to see that the conclusions reached here were not in conflict with this practical requirement. The enquiry showed that development and shaft sinking were more than ever urgent; delay in opening up the deposit would be expensive because of the rapid loss of profit through increasing dilution. For maximum profit, the ore-body (if it continues) should be exhausted at a much faster rate vertically than the present 30 feet (approx.) per annum and any increase of production should come principally through increase of the exhaustion rate. Dilution control must always remain strict for any increase in the proportion of rock sent through the mill would soon rob the Company of the profit benefit to be gained by increasing production. Finally, there is conflict between making money and mining as much metal as possible and the more restricted the output the greater must be the sacrifice of the tin and tungsten in the ground. Here is another reason for aiming to step up the production of the mine.

INTRODUCTION TO THE PROBLEM.

The tin-wolfram veins of Aberfoyle and Story Creek are found in folded NW striking quartzites and slates of Cambro-Ordovician age. The inset on the 1" = 100' drilling plan shows the location of the two mines in these rocks, a mile or more away from an intrusion of Devonian granite. The granite contact on the surface runs more or less parallel to the rock folding and appears to be steeply dipping where it climbs the slope west of Story Creek. This is about all that is known of this important contact although perhaps some inference, challenging the observed steep dip, can be drawn from the protrusion eastwards of the granite to the south of the mines and also from the persistent flatness of the Story Creek veins. Such speculation serves little purpose here. Fears have been expressed that the intrusion may soon put an end to these tin-tungsten deposits but there is at least the same sort of chance that the granite, whatever its effect may be, is still a considerable distance away from the present workings. To see that the way ahead is clear of this intrusive is one of the reasons for drilling deeply in the Aberfoyle campaign.

In and following the emplacement of the granite, both the intrusive and the enclosing Cambro-Ordovician rocks have been fractured. Most of these fractures strike parallel to the rock folding and dip SW - at angles usually a good deal flatter than the bedding although, as would be expected, there are also a great number of slips or shears parallel to the bedding which play a part in the story. The most prominent of these NW fractures is the group passing through the Story Creek mine. A second and subordinate system of fracturing strikes nearly N-S through the Aberfoyle mine where the dip is 70° W. Another N-S break is seen in the Cross Lode of the Story Creek mine dipping 30° W.

Along these cracks escaped the liquids and gases separated out of the granite and imprisoned in the course of its solidification. These solutions were charged with silica, tin and tungsten and as they rose rapidly through the broken ground

the pressure and temperature fell with the result that the escaping minerals were precipitated in the form of quartz veins with cassiterite and wolfram. Such precipitation does not take place evenly along the fractures followed for to build up an ore-body it appears to be necessary to pool the rising solutions and this is possible only where the rocks are broken open sufficiently to hold considerable quantities of liquid or gas in semi-stagnant flow. Profitable deposits are only found where the ground has been opened up in a sort of wound and the extent of the deposits will be just as finite as the wounds they fill. There is never much quartz or metal along the tighter fractures feeding these pools and in almost every mining field there are barren shears and faults like the bedding slips of the Aberfoyle area.

The ground of course becomes tighter with increasing depth and there is a decided tendency for the deeper wounds to become smaller and more widely spaced. But this tendency is not of serious moment in a shallow mine like Aberfoyle for deposits of this kind are known to considerable depths. What concerns this exploration problem is the recognition that wounds, whatever their depth, are finite and that structural changes alone may tighten ground and interrupt the continuity of a deposit.

The uneven precipitation of quartz cassiterite and wolfram finds expression also in the changing proportions of tin and tungsten. At Aberfoyle the tungsten tin ratio is increasing on the bottom levels but it is not known whether this means an increase of wolfram or decrease of cassiterite. It is possible that with increasing depth there will be such a change in the relative proportions of tin and tungsten, but it is another matter to ascribe the changing ratios on the bottom levels to this possibility. For metal ratios will also probably be affected by structural changes and are therefore liable to fluctuation whatever may be the overall tendency in depth. The tungsten tin increase on the bottom levels of the Aberfoyle mine can be a fluctuation of local structural origin.

The ore filled wounds are commonly developed by the intersection or bending of fracture systems (or of structures which control the fracturing) and it is ultimately tension that opens the cuts in the ground. These broad relations are hard to diagnose at Aberfoyle because to the north, south and west of the mine the Cambro-Ordovician rocks and their tin veins are extensively concealed below a thin layer of later Permocarbiniferous rocks and wash. The main part of the deposit itself was hidden by this cover. The first important fact is that the mine is on the line of Story Creek fracturing. This fracturing cannot be followed through on the surface to Aberfoyle because it passes below the Permo-Carboniferous cover referred to above. The second fact is that the main group of Aberfoyle veins strike W of S in a system of N-S fracturing, which is completely concealed beyond the mine. Aberfoyle occupies, therefore, as the drilling plan shows, the most important looking intersection in the district - that between the main lines of NW and N-S fracturing. The N-S fracturing dominates the intersection and it looks as if the weaker Story Creek line has been sharply bent at this intersection into the E of S course of the Eastern Vein and Aberfoyle fault which make an acute angle with the W of S Aberfoyle veins. It is possible, as suggested by the inset plan, that fracturing continues along this new E of S course into the granite to the south of the mine. This thought does not mean that there will be a continuous extension southwards of the Aberfoyle fault; the exposures south of the mine suggest rather a left handed echelon arrangement of this fracturing.

The intersection picture looks complete in that it requires no other ore-bodies in the environment of Aberfoyle. For another intersection there must be another line of fracturing and there is no evidence of this exposed. The best chance appears to be a line parallel to Aberfoyle (i.e., belonging to the N-S system) under the Permo-Carboniferous rocks to the west of the workings; and if there is another such NS - NW intersection it is likely to show an ore arrangement and pitch similar to that of the Aberfoyle mine. This chance and idea have been given a

good deal of weight in the drilling planned bearing in mind the fact that the arrangement and pitch of the Aberfoyle mine have still to be determined.

It is interesting to note that there is another intersection between N-W and N-S fracturing in the Story Creek mine but here the N-W line is dominant and has not been bent.

Another point which may be significant is that the Aberfoyle mine lies within, as the inset plan shows, a zone of tin veins which corresponds with a conspicuous N-E trending trough in the eroded floor on which the Permo-Carboniferous formation was deposited and it is again interesting that in this zone the granite contact becomes irregular and deeply embayed.

With this background in mind, introductory thinking can turn to the geological relations exposed in the underground working of the Aberfoyle mine. The deposit has been pretty fully (not completely) developed down to the 4 level. The plans and sections show a group of veins striking W of S and dipping W about 70° . Isolated to the east, like another leg of the vein pattern, is the relatively unimportant Eastern Vein striking E of S and dipping W about 50° . The best vein in the main western group (and in the mine) is No. 26 and right through the piece it has to be borne in mind that the 50 vein, on its east, and 40, 40 south and Western veins, successively on its west, are a good deal smaller than 26 above the 4 level. For as well the 26 and its satellite veins are arranged in a closely spaced right handed echelon, the significance of which is qualified by this predominance of 26. The same echelon is barely discernible in the sections, but it is seen to be right handed looking north whereby the more westerly veins have a tendency to continue deeper into the ground. Because of this echelon arrangement the main part of the Aberfoyle deposit (i.e., leaving out the eastern vein) above the 4 level is pitching S-W about 50° and, following the usual practice of naming as 'probable' the straight projection of a known pitch, this course has been labelled 'Probable' on the 1" = 100' drilling plan. It

expresses the difficulty of the Aberfoyle problem that there is uncertainty about employing the straightforward projection of any known pitch in the mine and within the range of possible pitch it is going to be difficult to select any one as probable.

THE ABERFOYLE AND '40' FAULTS.

Inseparably involved in the ore extension problem are the rather intricate relations of the Aberfoyle fault. This prominent break was found dipping about 60° W as soon as the mine was opened and it was seen then to truncate abruptly the thin layer of Permo-Carboniferous rocks over the main part of the deposit. The truncation could only be explained by post Permo-Carboniferous displacement by the fault whereby the western or hanging wall of the break had dropped at least 30 feet (the thickness here of the P.C. layer) either by normal faulting or, as can be seen now, by some flatter dislocation of west block north. It appeared certain therefore that there would be displacement of the tin veins by the Aberfoyle fault.

Nowhere in the mine to date has there been found any proof of this inferred vein displacement. For that matter there is so far only one exposure, the 700 S Rise from the 5 to the 4 levels, which even permits such a displacement and that interpretation is very doubtful. Instead the veins are seen to avoid the fault or run gently and tangentially alongside or even into the break with no sign of being out, broken into pieces or dragged as the inferred vein displacement would require. There is still further warning on the point in the close relations between the vein pattern and this fracture, relations which only appear to fail where (and if) a branch of the fault passes beyond the deposit below the 5 level. Quite as certainly as the Permo-Carboniferous evidence of post vein movement, the underground exposures show that the Aberfoyle fault was there before the quartz came in. More than that, the Aberfoyle fault is an integral part of the vein fracturing if there is to be any understanding of the coincidences discussed below.

There looks to be an easy explanation of these conflicting observations. For there is sure evidence of later movement in the internal crushing of the quartz in situ where the veins approach and enter the break and probably the same slow grinding action is responsible for some or all of the tin in the mud or

gouge within the fracture. Any later settling or shove of the rocks would readily pick this break and post-quartz movement is a common feature of pre-quartz fractures. But the easy way out of this and remaining problems will not be stressed for the function of geology in exploration is a questioning refusal of any conclusions where there is doubt and the slim evidence to date of actual vein displacement by the Aberfoyle fault is a very perplexing feature of the mine.

A structural analysis of the Aberfoyle fault divides it into eastern and western elements. Both elements closely or roughly parallel the eastern vein fracturing (the eastern leg of the vein pattern) so that they dip W less steeply than the main group of veins. The eastern element hugs the hanging wall of the Eastern vein all the way down the mine while the western slowly crosses the main vein group passing from its footwall on and above the 1 level to its hanging wall on and below the 5.

The Aberfoyle fault accomplishes this dual role in a curious way. On the 1 level the western element runs parallel to and in the footwall of the 50 vein while to the south the eastern element runs parallel to and in the hanging wall of the Eastern Vein. To satisfy these two structural positions the fault has to be bent into a zig-zag course like an open S. Going down the mine this S shape, with its two bends, is progressively ironed out (with the downward convergence of the Eastern vein) so that the zig-zag is barely discernible on the 3 level. Here it should be noted that the western element approaches now the 26 vein at the north end of the mine, but the two element character is still preserved for with the failure of the zig-zag solution the fault divides, below the 3, into its two components both of which are now free to run the full length of the mine. This splitting of the break is nearly horizontal, the junction either pitching flatly north, as interpreted on the plans and sections, or flatly south, a possibility suggested by the ore extension ideas even though it does not fit satisfactorily the few exposures. The eastern element is

now, below 3, the footwall branch of the Aberfoyle fault and this continues to accompany the Eastern Vein down the mine so that both fault branch and vein converge on the main vein group until they are alongside on the 6 level. At the same time the western element, below 3, makes the bigger hanging wall branch of the fault. At the 4 level this branch runs in the footwall of the 50 vein near Spiers shaft and going north slowly transgresses the vein pattern until it engulfs the 26 vein which is within the fault in the northern stope of the level. Below 4, the hanging wall branch transgression speeds up and the fault goes right across the vein system to its hanging wall on the 5 level without any apparent dislocation of that system. This western fault has not been found on the 6 level and it either dies out (following its union with the 40 fault) or it continues its relatively flat dip to pass beyond the deposit and workings. It is possible therefore, but not at all certain, that the western element of the Aberfoyle fault has escaped below 5, from the vein pattern and any such escape is almost bound to influence, possibly even decisively, the extension of the deposit unless this one piece of doubtful evidence is accepted as reason for refusing any meaning in the extraordinarily persistent association between the Aberfoyle fault and the Eastern vein, an association which, it will be seen, fits well into the ore structural picture of the mine. The possible escape of the fault is another point to remember.

The transgression of the main vein system by the western branch of the Aberfoyle fault is one reason for the geological difficulties. On the 5 and 6 levels there are, excluding the Eastern Vein, two veins and these in section line up well with the 40 and 26 veins of the 4 level. The agreement becomes more convincing still when it is seen, as discussed below, to resolve in a satisfying way the third dimension of the echelon pattern of the veins. For this reason the veins on the bottom levels have been named "26", "40", "40 South" and "Western Vein." The commas are added because there is doubt about this interpretation. This doubt was introduced by the Rise at 700 s,

the only opening to date connecting 5 and 4 level veins. The Rise starts on '26 vein', and follows it up to the 4 level and the vein curves gently into and remains in the footwall of the hanging wall branch of the Aberfoyle fault to come out in the position of 50 and not 26 on the 4 level. As seen in the 700 S section there would have to be a displacement drop of about 40 feet across the fault to make '26' and 26 one vein. This is the displacement required by the dropping of the Permo-Carboniferous formation at the surface and it must be conceded therefore that this vein correlation is still a possibility. But the next chapter will show alternative explanations of possibly considerable significance. Because of these alternative explanations (arising out of the displacement issue of the Aberfoyle fault) the ore structural features of the mine will have to be examined first assuming that the '26 vein' of 5 is 26 and secondly assuming that this interpretation is not correct. The Aberfoyle fault has therefore all the appearance of belonging to the vein fracturing of the mine and affects the problem even more than that because its transgression leaves in mid-air the correlation of the veins on the bottom levels.

There is another fault like Aberfoyle except that it is a less prominent break and very much less persistent. It is interesting that this fault is closely associated with the main vein group as Aberfoyle is with the Eastern vein. This is the 40 Fault, so named because it marches with the 40 vein, which occurs in its footwall, occasionally in its hanging wall and sometimes within the break. The 40 fault must belong to the vein fracturing and be older than the quartz and this is further evidence in favour of the view that the Aberfoyle fault is also an old break. Going south the 40 fault curves across the south end of the 40 vein and continues into 26 vein country where it is lost.

It is possible to tie this faulting even more closely into the vein pattern. For right through the mine there are a number of N-S shears or slips parallel to the veins and these two faults. The main vein group is in fact in a zone of N-S shearing

and the picture of the Aberfoyle mine at the intersection of N-W and N-S lines of fracturing depends a good deal on this insight into the fault pattern of the mine. In conclusion, it should be noted that many of the minor shears or slips show the same left hand curving, going south, as the 40 fault. This horse-tail kind of pattern is well seen on the 5 level and it is thought there may be some relationship between this and the northern bend of the Aberfoyle fault and that all this fault bending has something to do with the ore distribution.

EXTENSION OF THE ABERFOYLE DEPOSIT.

West of and within the main vein group and west and east of the Eastern vein there are other smaller veins and the whole swarm of veins and faults slowly converge northwards like the ribs of a partly opened fan. The same radial pattern is strikingly seen in section where the convergence is downwards, and the arrangement was recognised very early in the mine's history. There was never much doubt that this fan-shaped arrangement of the veins would have some bearing on the extension of the deposit. To find this out it became necessary to portray the structure in its three dimensions and compare it empirically with the known extent of ore. The empirical treatment faced the handicap that all the information to date is within the structure permitting much the same view as a grub would have of the sphere of an apple while boring around inside.

With convergence northwards and downwards the fan is clearly tilted on the whole to the south. There is not, however, too much geometrical precision about this rudely radial pattern to permit a measure of the tilt and there are actually a number of focal points in the convergence. Sticking to the broad features it is not difficult to extrapolate the fan pattern to a root north of the mine. It is then seen that this root plunges very steeply down to the 2 level. It is possible that the plunge here, whatever the overall southward tilt may be, is even to the north and comes under the rock folding control to be discussed later. Below the 2 level the fan takes on its expected tilt and the pitch of the structure rapidly flattens to about 30° S. Below the 6 level there seems to be still further flattening and from 900 S to the end of information at 1300 S the fan arrangement looks horizontal though this important point cannot be settled by the present limited exposure. Whatever this ultimate flattening the root of the vein arrangement follows an elliptical course like the keel of a boat and keel is the name that has been employed to refer to any focal points in the structure. It should be noted that fracture intersections quite often follow an elliptical course and there is not

much doubt that this broad picture of the fan is right.

This root is defined by the convergence of the two legs of the fracture pattern, viz:- the main vein group and the Eastern vein and associated Aberfoyle fault. For precise plotting purposes, the projected junction of the 26 and Eastern vein has been employed and this keel is shown on the 1" = 100' drilling plan.

The first evidence of south pitch in the ore arrangement which may agree with the fan structure is in the rather flat top of the 40 South vein and it is possible that the top of the Western vein will show, when reached, the same coincidence.

The 50 vein affords the next clue. The northern end of this ore corresponds roughly with the elliptical course of a keel with steep pitch above 1 level and a flat south pitch from 1 to 4 levels. It is very likely that this end of 50 is one of the keels, that represented by the convergence of the 50 vein, of the western vein group, and the 2 level's 10 vein of the eastern fracturing. Not only does this raise the interesting point of a possible nesting of the keels, one within the next, but it looks as if the 10 vein is associated with the western element of the Aberfoyle fault just as the Eastern vein marches with the eastern element. In other words, the 50 vein is stopped by its convergence with the (western element of the) Aberfoyle fault and it should be noted here that there is evidence on the surface that the same fault convergence marks the northern limit of the deposit here.

In the study of this 50 vein detail every attempt was made to explain the arrangement by allowing the Aberfoyle fault to cut off 50 and displace it into the 10 vein position. The trial failed at every point. The 50 vein is not cut off by the fault; it dies with the convergence - for the most part before the fault is actually reached. The 10 vein is not 50; by no displacement arrangement considered could they be made to fit together.

The 10 vein is regarded as the first, or most western, of the eastern fractures. It is a small crack and develops ore

width only near its keel position. If this is the control the ore shoot should pitch flatly south below the 2 level; the impression is that it is not very persistent. But this projection carries the 10 vein to the position, in the footwall of the fault, occupied by '26 vein' on the 4 level at the top of the rise from 5 level at 700 S. One alternative, therefore, to the correlation discussed above of '26 vein' with 26 is that the '26 vein' on the 5 level belongs to the eastern leg of the fracturing which is here making ore near its keel position. If this is so, the 10 - '26 vein' association is very good evidence of ore influence by the fan structure.

The 12 vein, also on the 2 level, tells the same story more clearly. This ore is on the Eastern vein and like 10 it is near its keel defined by the convergence between the Eastern and 26 veins. This ore should also follow the south pitch imposed by keeling. Its position by this projection has not yet been opened up on the 3, 4 and 5 levels (see 1" = 30' mine prospect plan) but it has been entered recently on the 6 level both in the short drive near 800 S and in the rise near 900 S. Ore widths have again been found here on the Eastern vein near its keel and there is no question now of some relation between the arrangement of the deposit and the fan structure. The issue remains as to what is the extent of the relationship.

Finding the 12 vein on the 6 level does not mean there will be continuous ore in this fracture between the 2 and 6 levels. There is a suspicion that the 2 level position is a particularly good one, for 10 vein as well as 12, at the sharp change of keel pitch from steep to flat. The persistence of keel ore is in doubt. Where this thought may have value is in the analogy that perhaps the whole of the Aberfoyle deposit is also localised by this change of pitch and this thought raises the first doubt about the downward extension of the mine.

The next question is if the 10 vein means a bottoming of 50 does the similar 12 vein mean a bottoming of 26. There is an ominous shortening of the important 26 vein going north on the 4

level in exact agreement with this fear. The argument now faces the uncertain correlation of the veins on the bottom levels below the hanging wall branch of the Aberfoyle fault. The alternative that the '26 vein' of the 5 is keel ore in the eastern vein group has been examined and this is the place where the ore relations must be re-examined, assuming that the '26 vein' of the bottom levels is, as appears on first enquiry, the 26 vein of the upper levels.

If that correlation is correct the northern shortening of the 26 vein continues progressively on the 5 and 6 levels exactly as if the vein is bottoming, like 50, on a south pitch parallel to the keel. Just as 50 ends with the convergence of the western element of the Aberfoyle fault so 26 would be ending with the convergence of the eastern element of that break. Under the '26' = 26 assumption there is every bit as much coincidence between the ore arrangement and fan structure as was seen under the alternative view that '26' vein was the keel of an eastern vein. The argument, therefore, survives this uncertainty and either way the fan is showing up as the dominant ore structure of the mine and either way the disappointing results of the '26 vein' on the 5 and 6 levels are explained.

The possible successive bottomings of 50 and 26 veins has however another impact on the planning of exploration. For it would underline the echelon arrangement of the main vein group in its three dimensions. The ore of 50, 26, 40, 40 South and Western vein could now be looked at as five overlapping panels carrying the deposit SW, at 50° on the course marked as 'Probable' on the 1" - 100' drilling plan. To continue this pitch, the 40, 40 South and Western veins would have to pick up on the bottom levels to recompense the bottoming of 50 and 26 and as the mine goes deeper still further veins to the south-west would have to be found.

There is a good deal of doubt whether the echelon will continue down this 'Probable' pitch but it is instructive to see how such an echelon could be arranged in a fan structure. Already there is a suggestion of a 50-10 keel followed by a 26 - Eastern

vein keel. Carrying this on, the next keel would be 40 with a vein to the east of the Eastern vein and if the right handed echelon of the western vein group is then to continue, it would need, for this nesting, a matching left handed echelon of the eastern vein group. Keel within keel may well be the pattern of the known veins but this does not mean, of course, that the spreading echelons will continue. Another possibility is that the echelon of the western vein group will be confined above the Aberfoyle fault, i.e., the fault convergence which may have already bottomed 50 and 26 would also bottom the 40 and any more western veins.

This is as far as the ore relations of the fan structure can be traced in the mine. To gain a clearer picture it is necessary to look at these relations in the light of ore structural experience with other deposits. On the 5 and 6 levels there is a slight but definite steepening of both the western and eastern veins. This immediately suggests that the fan arrangement results from a flattening of the vein system and there are a number of instances where ore-bodies are controlled by just such bending and flattening of veins. But there are snags in the way of drawing this parallel. If the vein steepening is part of the fan structure the change of attitude should be seen at the north end of the mine in a change of strike. There is no evidence so far of any such south pitch of the vein steepening. Again if the deposit has been the result of vein flattening, it is difficult to understand why the flattest eastern veins are so poor. But further progress can still be made by thinking of the fan structure as an intersection between W of S shearing and the E of S Aberfoyle fault. Fracture intersection is probably the most common of all ore controls. It may be significant then that the fault is twisted like a propellor blade from a 50° dip at the south to a 60° dip at the north end of the mine, while the W of S shearing shews an opposite warp from a 65° dip at the north to a 75° dip at the south end of the mine. It is as if the W of S shearing has been flattened by the fault and at the same time the fault has been steepened by the W of S shearing. Experience in other mines reinforces the view of the importance of

the fan structure in the arrangement of this deposit.

There is then the observation of ore extending with the fan structure, the inference that this structure results from an intersection with the Aberfoyle fault and the parallel that such intersections do commonly make ore deposits.

The conclusion has been therefore tentatively adopted that the Aberfoyle deposit is confined to and will extend with a fan of veins which is pitching south flatly if the full panorama of fractures has been already exposed or south-west more steeply if there is any further continuation of its echelon pattern.

The chance of a flat pitch is in harmony with the rather sudden southern run of ore on the 4 level and also in harmony with the vein arrangement in the other mine at Story Creek. If the south pitch conclusion is right, Spiers shaft will ultimately pass into the underwall of the deposit. The fears held that the veins will bottom near the shaft below the 6 level are therefore supported by this survey but this possible bottoming evidence is seen here only to be the result of pitch.

DOUBTS OF CONTINUED EXTENSION.

The puzzling features of the bottom levels which determined the Company to call for a geological examination have been considered and the view taken that there will be no post-quartz cutting off of the veins by the Aberfoyle fault and that the 5 and 6 level results, as far as they have been worrying, can be explained by a south pitch. Unfortunately, the prospect is still not out of the woods.

The fan structure follows an elliptical course resembling the keel of a boat. Variations in the arrangement of a deposit of this kind convey a warning against relying on any continued ore extension for few deposits survive important changes of pitch. The fear is strengthened by the observation that the elliptical course has not left much room for extension below the south end of the 4 level and there are examples in other mines of similar encirclement of a deposit by a curving fracture intersection.

The chief hope here is that the pitch of the fan has not flattened to horizontal between 900 S and 1300 S as appears to be the case. It is a reasonable hope for the evidence on this point is meagre and far from conclusive. If the pitch continues nearer its 30° down the first evidence of it will be seen in a divergence southwards ~~xxxxxxxxxxxxxxxxxxxx~~ on the 6 level, between the Aberfoyle fault (and its 12 vein) and the western veins and this chance is at least alive on the evidence of the recent foot-wall drilling near 1100 S. It is interesting this calling again for a bending away by the Aberfoyle fault with the thought, that the 6 level at the shaft resembles the 1 - 4 levels at the north end of the mine. It would mean that the fault bending of the upper levels has been ironed out only to step south in depth and that the bends continue and remain with the fan by steps. It is possible that not only do the fault structures step south but that the entire break pitches south, which would mean that the Aberfoyle fault would also die below the 6 level at the shaft.

Another hope is that the tilt of the fan is undulating. While it is unlikely that the deposit would survive any undulations

there would be a good prospect of ore coming in again where and when the horizontal fan resumed its steeper plunge. Pitch undulations are commonly a feature of ore repetition.

There are also doubts about the ore extension if it must rely on a continuation of the echelon pattern of the veins. The 40, 40 South and Western veins have not so far widened up like the 26 vein on the upper levels and the strength of these western veins would be the strength of an echelon extension of the deposit. Again, the hope is that the limited evidence to date is misleading. There is still room for the western veins to pick up and again it will be the 6 level southwards that will tell the story.

Should the extension fail through a failure of the echelon pattern to continue there will still be a repetition prospect in depth but this time without any clue like pitch undulations. The lack of clue is not as serious as may appear for the search for ore repetition is anchored to 'maxima and minima' reasoning which relies little on any geological projection. If there is another deeper isolated vein group it is likely to be because some favourable condition like rock folding, discussed in the next chapter, recurs somewhere down the course followed by the master-structure which is thought to be at Aberfoyle the interection between two major lines of fracturing.

The next doubt of continued ore extension is introduced by the isolated character of the Eastern vein. This ore shoot appears to be complementary to the main vein group in its relation to the southern bend of the Aberfoyle fault. Significantly the ore body dies out below 3 level with the ironing out of that bend just as the western deposit may die out with the ironing out of the northern bend. This detail of the Eastern vein is not puzzling but it is difficult to see how this ore fits into the broad arrangement of pitch. The issue may be unimportant (the Eastern vein is small) and without bearing on the exploration problem. More likely the occurrence means:

1. Emphasis of the boat shape of the fan with its fear of a finite structure robbing the mine of much further ore extension.

- or 2. Repetition south eastwards in the direction of Story creek fracturing. Maybe most of the ore in this S E position has been eroded away, i.e., the repetition gets deeper to the N W.
- or 3. Some sharp bending of the ore arrangement or pitch whereby the deposit develops on the S W course with lean or barren intervals on the N E changes.

These alternative ideas are advanced less in the hope of pinning down the truth of it all than to show how easily the argument, even if right most of the way, can go astray at the end.

The last doubts derive from the fact that there is as well as the fan another competing control of ore pitch. This is rock folding and the importance of this influence will be shown in the next chapter. The whole view of ore extension or repetition is radically concerned with just how important is this rock folding.

INFLUENCE ON ROCK FOLDING.

The mine is on a crumpled S W limb of an anticline, the bedding and folding of the district all striking N W. The Story Creek fracturing follows the same direction and it is thought that these flat tin veins are in part the tension result of shearing in the bedding grain of the rocks. The rock folding influence in the Aberfoyle mine is really, therefore, the Story creek component of the problem.

There is locally some overturning of the beds but on the whole the folding is steeply or even vertically arranged. The crumpling continues throughout the workings and embraces a number of anticlines and synclines which from north to south are syncline S 1, anticline A1, S 2, A 2, and S 3. Between S 2 and A 2 there are two or three minor folds which have been omitted from the ore study and there is also here a small area on all levels where the bedding is flat. Another minor fold omitted is on the S W limb of A 1. It should be noted that these smaller crumples play the same sort of role in the ore arrangement as the larger folds; they are, in fact, more important than their dimensions suggest.

There are a great number of bedding slips, fracturing of the same type as the backs of the Bendigo field. The biggest is the quite impressive Western Fault on the S W of A2 and it is interesting to see this fracture cross S 3 just as some of the Bendigo backs break across centre country. There are other examples of strong fracturing but the great majority of the exposures show the slips to be parallel to the bedding. The cracks tend to be crowded in the vicinity of the fold centres and they are therefore particularly plentiful with the crumpling, between S 2 and A 2.

The weight of evidence shows this fracturing to be old and, like the other faults, to have started before the quartz veins were formed. The 40 fault and other N - S shears are displaced by the slips but no exposure was seen of an intersection between bedding fractures and the Aberfoyle fault. It can be

said here that there does not appear to be any serious displacement of the folding by the Aberfoyle fault, a point meriting earlier attention, were it not that it appears to have little bearing on the exploration problem. There has also been (some) post quartz movement along the bedding slips and the whole issue of their pre-quartz versus post-quartz movement is difficult to determine. The net result in any event is that the veins are offset feet or inches by the slips and the offset, with scarcely an exception, is to the right. (Cf. echelon)

This right-handed stepping of the veins takes place whether the slips dip S W or N E and this independence suggests that the displacement is horizontal rather than vertical. There is some doubt about this because similar throws in the Story Creek mine are seen to be due to a prevailing thrust of S W block up, a movement that also leads to right handed offset. But whether the dislocation is horizontal or vertical it would have the effect of pulling open the N-S shears or cuts of the vein system. In other words, if the fold fracturing started before the quartz it should have some effect on the ore arrangement.

Experience has shown that the usual practice sampling and assay is not worth its expense in this mine. The lack of stope assay data is a serious handicap to ore structural analysis and it is not known, therefore, whether there is any enrichment by the bedding faults. It was the writer's impression that the veins tended to be wider at the offsets and Mr. Jones suspects there may be a tendency to some tin or tungsten enrichment in these positions in the stopes. No dependable conclusion can be drawn.

The influence of rock folding on the arrangement of the deposit can, however, be seen without the help of this detail. For there is an unmistakable connection between the folded and fracture patterns not only in the location of the veins but in their disturbance in the vicinity of fold centres. The 26 vein on all four levels extends from S1 to A2, with its ends near enough to these fold centres, except where the vein shortens at

the north end of 4 level as required by the fan structure. Similarly the 40 veins extend between A1 and S3, the continuity of the veins being broken and offset in the general vicinity of S 2. The south end of the Eastern vein also marches with the folding, and it is not understood why the north end does not do the same. The 50 and Western veins similarly fail to correspond with the folds but this failure does not challenge the 26 and 40 observations for both 50 and Western ore, on and above the 4 level, are outlined, as already discussed, by the south pitch of the fan structure.

Because the folding is N W and nearly vertical this vein and fold coincidence means a steep north (about 70°) pitch and while there is no great precision in the arrangement there is no doubt of a pitch element in the deposit approximately at right angles to the south pitch of the fan structure. The contrary pitch is seen again in both bends of the Aberfoyle fault which instead of going down south (as would be expected) continue steeply north in the general neighbourhood of A 1 and S 2. Indeed it is now likely that the steep pitch of the fan on the 1 and 2 levels is the result of the folding grain and, if so, the pitch undulation reflects the competing controls of fracture intersection and folding. Virtually clinching the argument is the fact that most, if not all deposits, exhibit a two way control as it is almost impossible to have an intersection of structures without a pitch and counter-pitch. The view of a deposit is nearly always concerned with the interplay of two pitches, one of which will be locally or continuously master of the situation.

The issue however at Aberfoyle is not as clear cut as this. For the influence of rock folding also dovetails harmoniously into the fan arrangement of the veins. Broadly viewed the mine is on the S W limb of a large anticline and on the whole the beds and fractures dip S W, so that the intersection between Story Creek fold fracturing and Aberfoyle shears has a S W pitch component which is modified and masked because of the steep arrangement of the fold centres. A fracture like the Western fault is

capable of carrying ore locally to the SW. Further the echelon arrangement of the veins pitches also SW square across the NW line of folding. Exploration planning has therefore to accept the fact that the influence of rock folding, not only introduces a contrary north pitch into the arrangement but also, in another way, reinforces the pitch of the vein pattern along the S W course marked on the 1" - 100' drilling plan as 'Probable'.

It is on the cards that the deposit has been localised by the fold crumpling, and while the possibility is not given much weight it is well to look here at the consequences of any such environmental control. To stay with the known crumples the deposit would have to pitch steeply north and if continuous extension in this direction is unlikely, then perhaps steep north is the direction of ore repetition. Against the reasoning is the fact that such crumpling does not usually have great persistence down the axial planes.

On the other hand, if the pitch is to the south or south-west, it would be necessary, pursuing the same thought, for the rock crumpling to continue across the S W limb of the anticline. The crumpling may of course continue, but it is more likely to do so irregularly and the more folding irregularity the more the tendency to ore repetition in this direction rather than continuous extension. Whether the deposit is confined, by rock crumpling or not, this environmental thinking does help in the understanding of ore extension versus repetition.

In conclusion the influence of rock folding tends to impose a steep N pitch on the northern and southern ends of each vein. While this arrangement appears to be restricted within the south pitching fan of fractures, there is still the chance of ore continuation steep N by repetition. At the same time the folding reinforces the S W pitch at 50° so that at the end of this reasoning the course labelled 'Probable' on the 1" = 100' plan may be regarded as the probable. The selection finds support also in the idea of a pitch undulation and in the fact that the S W course is midway within the range of possible pitch, viz: the flat south of the fan to the steep north of the rock folding.

PROPOSED EXPLORATION.

The planning of exploration takes advantage of the geological conclusions reached and at the same time prepares for any conceivable contingency suggested by any doubts or uncertainties in the geological argument. It is evident that at Aberfoyle there is the widest range of contingency both in pitch and extension versus repetition. Even so, by straightforward planning, it is possible to cover in a critical way the whole prospect field with half a dozen holes. But the difficult part of the job still lies ahead in the decisions that will follow on the drilling results, particularly on the results of the first hole. All that has been written above will bear on these decisions and if the review has been long and technical, it is because the geological problem of Aberfoyle has proved to be one of exceptional difficulty.

The planning has been recorded on the 1" = 100' drilling plan and section and on the 1" = 30' mine prospect plan showing the targets underground. The recommended work has been summarised in the frontispiece of this report.

The first critical and urgent step is to resume sinking of Spiers shaft to open No. 7 level and drill surface hole S 1 at the location given in the frontispiece summary. The drilling station, at 1613 W. is 20 feet further west than the position shown on the 1" = 100' plan and section because, as explained in the letter with this recommendation, it was later decided to increase the allowance for creep. S 1 will find any extension of the deposit unless it turns to a flat south pitch or bottoms. If the pitch flattens, the extension will be proved by the development of the 5 and 6 levels. Hole S 1, with the opening up of the bottom levels, will settle (if all goes well) whether the deposit continues in depth or not and will find any extension whatever may be the pitch, steepening or flattening of the veins. The drill hole will be also a useful probe of concealed ground to the west of the mine.

The opening up of 6 level southwards will be particularly significant in its bearing on the exploration problem. The 1" = 30' mine prospect plan indicates the targets here, viz:

Targets.	See 1" = 30' plan about.	Significant whether or not.
'40 South'	1200 S West.	These western veins become important.
'Western Vein'	1300 S West.	
12 Vein	1000 S East.	There is divergence south-wards of Aberfoyle fault and western veins.

Useful also will be information from between the 5 and 4 levels where the vein correlation is in doubt. Driving is in progress following the '40 Vein' north on the 5 and 6 levels and the '40 South Vein' south on the 5 level. The 5 level should also look for

See 1" = 30' mine prospect plan about.

'Western Vein'	1300 S West
12 Vein.	600 S East.

With the completion of S 1 and 5 and 6 level work the way ahead will be decided. The following targets for surface drilling are in mind:-

T2. Should S 1 and/or 5 and 6 level results reveal ore extension this hole necessary to show more closely ore length and pitch in depth. T2 is located safely within the projection of the deposit to show at the same time that there is substance and length in the extension and that the way ahead is clear of granite. Position on 1" = 100' plan which assumes 'probable' pitch is liable to change, e.g., if pitch proves to be flat target would be moved hundreds of feet south and east.

T4. Should S 1 etc. show no important extension of known deposit, this hole would be aimed at ore repetition down the course of the master structure which, on present evidence, is the

intersection between Story Creek and Aberfoyle fracture systems. Consideration would be given, if necessary, to the course that pitch undulations would follow.

Hole would be 2000 feet to reach as far as practicable beyond bottom of known deposit, i.e., maximum spacing possible. Position on 1" = 100' liable to change with improved understanding of master structure.

T3. Should all previous drilling fail to locate the deeper ore, this hole would be the second shot at ore repetition down course of the minor structural control which appears to-day to be rock folding. Again maximum spacing practicable is wanted and target position on 1" - 100' plan should be moved N W to permit a 2000 foot hole remembering that T3 should not be more than target deposit length away from T4.

T7 and T5. After Aberfoyle in depth drilling completed. The two holes will make a practically continuous test across the full width of concealed ground at critical positions spaced about 700 feet to the N and N W of ground already explored. Search particularly interested in chance of any line of fracturing parallel to Aberfoyle. Location depends on whether T3 is drilled or not. The position of T5, a 30° hole, determined by pitch that is assumed for target ore and location may be changed even from a W to a N E course. Likely to assume that target ore pitch will be the same as pitch of known deposits and this is one reason for drilling the concealed area after drilling Aberfoyle in depth. The position of T7, a 43° hole on the 1" - 100' plan, is not liable to as great change as T5 but it may be changed, for example, to a 30° hole.

T6. What drilling, if any, that follows will be determined by T7 and T5 experience. Caution particularly advisable because of risk of teasing results leading to useless expense. Drill holes in this country liable to fluke falsely attractive results.

T6, a 30° hole, fills in between T5 and the alluvial workings and should safely crosscut Story creek fracturing. If possible, therefore, test should continue further N E than shown on 1" = 100' plan remembering that hole should also reach for any fracturing, parallel to Aberfoyle, below the alluvial workings. Like T5, location of hole depends very much on pitch assumption.

T8. 30° hole exploring south of mine as T7 has explored north of mine and like T7 location on 1" = 100' plan not liable to great change. Spacing 700 feet away from ground already explored. Test must cover safe projection of Aberfoyle veins and the full width of the concealed ground to the east of this projection.

For this drilling it is recommended to employ one diamond drill with a safe range of 2000 feet and using A rods. One machine should handle 5000 feet of drilling within a year.

Hole S 1 will be stopped when it has with certainty passed its objective as seen in the 1" = 100' section; the 1200 foot figure given in the frontispiece is no more than an estimate of the necessary length. Hole angle checks, with glass tube and acid, should be made on the average about 300 feet apart. Core should be stored in boxes with five 5 feet rows, i.e., 25 feet of recovered core per box. The drill log should note where broken ground, pug or water was encountered because faults are important in this problem.

MINOR UNDERGROUND WORK.

There appear to be a few gaps in the development of Nos. 1 to 4 levels notably at the north end of the workings. No great attention or emphasis has been paid to these minor targets for they must not be allowed to take men away from the urgent development of 5, 6 and 7 levels.

These underground prospects and their two drill holes, U 1 and U 2, are shown on the 1" = 30' mine prospect plan. The