

Gang Vein and Gulf Fault, Wirksworth, Derbyshire

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Abstract. The E-W Gang Vein meets the NW-SE Gulf Fault at a 45° angle close to the crest of the Bole Hill anticline in the Carboniferous Limestone. Neither of these fractures appears to offset the other laterally, although many veins in the Peak District show evidence of wrench faulting. An analysis of the limited field evidence, together with old lead-mining records, including those of numerous branch veins, suggests that the Gang Vein was a normal fault at first, possibly a series of en echelon fractures, but later in post-mineralization times there is evidence of dextral wrench movement. Movements were episodic during the changing stress field from late Dinantian to Late Westphalian times. The Gulf Fault and its partner, the Rantor Fault, were normal faults, with their main movement in post-mineralization times.

During the author's study of the mineral vein pattern around Wirksworth, it has become evident that there are considerable uncertainties and differing opinions about the amount and direction of displacement of the two major fractures, the Gang Vein and the Gulf Fault. Neither their intersection nor their structural history has been studied. While field evidence is limited, old geological and mining records throw some light on the matter. It is the purpose of this note to draw attention to the problem.

Geological background

The Gang Vein and Gulf Fault cut the Carboniferous Limestone of the Bole Hill area between Wirksworth and Cromford at the southeastern corner of the Derbyshire limestone massif. The limestone is folded into the Bole Hill anticline with a roughly east-west axis and a gentle easterly plunge, diversified by a slight doming in the middle part of the Gang Vein. The overlying Millstone Grit Series is less strongly folded. The stratigraphic sequence has been described by Shirley (1959) and in the Geological Survey Memoirs and Reports (Frost & Smart, 1979; Smith et al., 1967; Cox & Harrison, 1980; Harrison & Adlam, 1985). Stratigraphic nomenclature was revised by Aitkenhead & Chisholm (1982). Walkden et al. (1981) and Oakman & Walkden (1982) described the cyclic nature of limestone sedimentation in the Wirksworth area. Gutteridge (2003) and Cossey et al. (2004) have added further detail concerning limestone facies and correlation. General geological guides were provided by Ford (1999, 2003).

The stratigraphic sequence is shown in Table 1. A total of some 350 m of limestones are exposed: their base is not seen. No geophysical or other evidence of the nature of the basement beneath the limestone is available. The limestone sequence has two toadstones (basalt lavas) intercalated. The Matlock Lower Lava, about 20 m thick, lies close to the Asbian/Brigantian boundary under most of the area, thinning out southwards. It overlies the Middleton Limestone Mine,

but is not present in the Middlepeak Quarries. However, old mine plans and sections show it to be present beneath the Gulf and in the Rantor branch of Meerbrook Sough. The Matlock Upper Lava appears to die out before reaching the Bole Hill area (Walters & Ineson, 1981), though some allusions to a "Great Clay" in old lead mining records may signify either a thin Upper Lava or a thick wayboard. Several clay-wayboards (volcanic dust tuffs) are interbedded within both Bee Low and Monsal Dale Limestones (Walkden, 1972).

Descriptions of the mineral veins may be found in the Memoirs (Dunham, 1952, Dunham & Dines, 1946; Smith et al., 1967; Frost & Smart, 1979) and in Ford & Rieuwerts (2000). Details of the drainage soughs are in Rieuwerts (1987).

Gang Vein

This major mineral vein has an east-west course roughly along the crest of the Bole Hill anticline, though there is little exposure today. The early mining history was outlined by Kirkham (1953, 1963), though it is in need of revision in the light of recent archival discoveries, mostly by Jim Rieuwerts (*pers. comm.*). The outcrop of the Gang Vein lies in the rough ground north of Porter Lane, much obscured by grassed-over lead miners' waste hillocks. A length of some 1500 m can be determined from near Black Rocks in the east to the Gulf Fault in the west, with an extension beyond the latter to the west. The vein was worked from the

Namurian	Millstone Grit Series	Ashover Grit Edale Shales
Dinantian	Brigantian	Eyam Limestones Monsal Dale Limestones
	Asbian	Bee Low Limestones
	Holkerian	Woo Dale Limestones

Table 1. Outline stratigraphy of the Wirksworth area.

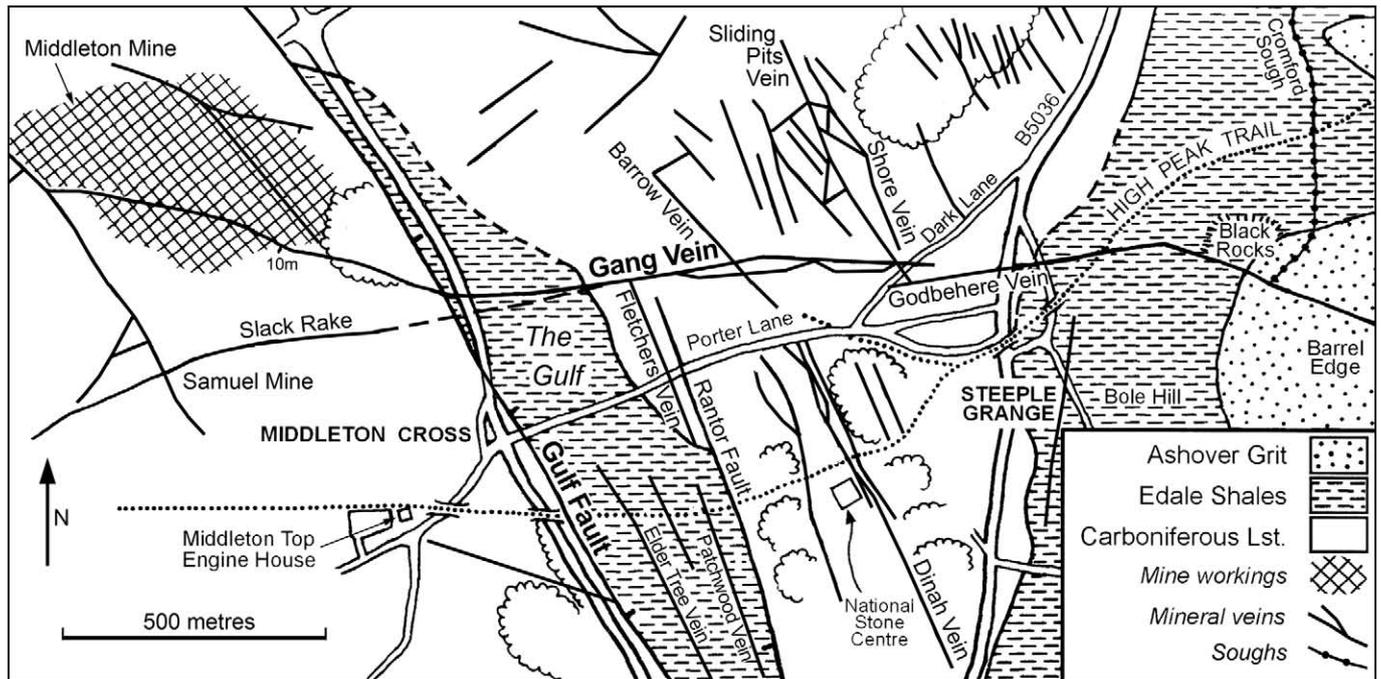


Figure 1. Geological sketch map of the Middleton-by-Wirksworth area showing the Gang Vein and the Gulf and associated mineral veins (based on an earlier version in Ford, 2003).

16th to the 19th century from about 24 named shafts at around 100-200 m intervals (Oakman, 1979), though early mining had many more (Rieuwerts, 1981 & *pers. comm.*). The named shafts are shown on mine maps compiled by Oakman (1979), Flindall (1974) and Rieuwerts (1980), and also on a series of 1:2500 maps compiled by the Barmaster (the principal lead mining officer), undated, but from around 1900-1910. In three places the vein splits over lengths of 200-300 m and lenses of limestone (“riders” in old mining jargon; Rieuwerts, 1998) up to 50 m wide lie between the two branches. It is possible that these splits represent echelon faulting but without access or detailed mine plans it is impossible to be sure. There is also a dextral offset of about 30 m near Dark Lane shown on several old maps: this displaces the eastern end of the Gang Vein to the south and the part to the east is known as the Godbehere Vein, once worked from the Cromford Moor Mines close to Black Rocks. The offset is aligned with a NW-SE vein to the north – Sliding Pits, along which Vermuyden’s Sough approached Gang Vein in 1651; Shore Vein is a northerly branch vein close by (Shaw in some mining records). Close to Black Rocks, Godbehere Vein curves somewhat to the southeast, and some maps show a fault splitting off almost due east, and downthrowing north at Barrel Edge, where the outcrop of the Ashover Grit is affected by landslipping. This fault does not appear on most old mine plans and its existence and nature remain uncertain.

Most of the Gang Vein was about 2-4 m wide, with galena, baryte and calcite as the main minerals and lesser quantities of sphalerite, pyrite and fluorspar.

There was too little fluorspar to attract the modern spar miners and the area was judged by Dunham (1952) to lie outside the fluorspar mineralization zone, which may lie beneath the Edale Shales down the plunge to the east of Black Rocks and Barrel Edge.

Godbehere Vein was worked from the Old Engine Shaft (= Gin Pit) adjacent to Dark Lane to the most easterly “10th Meer Shaft”, which is now run in, close to Black Rocks. The latter are generally regarded as a landslipped mass of Ashover Grit derived from Barrel Edge, though the crag may lie between two faults.

Gang Vein crosses the northern end of the Gulf (Fig. 1), but whether it is a fault cutting off the shale outcrop (Stephens, 1942) or not (Smith et al., 1967) is debatable, as the critical area is concealed beneath buildings and quarry waste. At least it can be said that the shales thin out to nothing before they reach Middleton-by-Wirksworth village. Most previous writers (e.g. Smith et al., 1967) have claimed that the Gang Vein was downfaulted to the north, but Carruthers & Strahan (1923) and Stephens (1942) argued that the throw was variable and in places was down to the south. Dunham & Dines (1945) also said the downthrow was to the south, though without stating the evidence. There have been few comments on either the amount of displacement or on the hade: some said that the hade was variable, north at the eastern end and south near the Gulf, though the evidence is far from clear. However, in a brief report on an exploration of one of the Cromford Moor Mine shafts on Godbehere Vein (close to the Black Rocks car park), Porter (1990) recorded that the shales were

30 m lower on the south side. His report included a photograph showing strong horizontal grooving along the walls of a stope. This clearly indicates horizontal movement, i.e. wrench faulting, at least after the emplacement of the mineral fill. Godbehere Vein was worked at a depth of some 150 m beneath the slope south of Black Rocks, where it was drained by Cromford Sough (driven between 1652 and c.1800, with several gaps; J.H. Rieuwerts, *pers. comm.*). Most of Cromford Sough was driven through shales and it intersected Godbehere Vein beneath the Barrel Edge escarpment of the Ashover Grit. At the intersection the north wall was limestone while the south was in shale. Deep beneath the dip-slope east of Barrel Edge, a branch of the later Meerbrook Sough drained workings about 30 m deeper around 1815. Internal pumping allowed workings to be taken nearly 50 m below the level of Meerbrook Sough. Other mining records indicate that when Cromford Sough was turned west along the "sole" (i.e. the lowest 17th -18th century workings), the miners took advantage of digging through shales along the south wall, confirming the southerly downthrow and demonstrating that the limestone dipped down the plunge of the Bole Hill anticline to the level of both Cromford and Meerbrook soughs beneath Barrel Edge.

Together the incomplete records show that the Gang/Godbehere Vein had a southerly downthrow of 30 m at least at its eastern end; it has a steep hade to the south at the eastern end (Porter, 1990). Its position close to the axis of a gently plunging anticline suggests that there was dextral wrench movement sufficient to place limestone against shale at the eastern end, perhaps over a length of more than 200 m. This displacement is not obvious on the surface outcrops, though roads and buildings obscure the position of the shale/limestone boundary: there may be an unexplained anomaly here. The post-mineral-emplacment wrench movement seen in Porter's (1990) photograph does not preclude normal faulting at an earlier phase, but no direct evidence is available.

Numerous mineral veins branch off both sides of the Gang Vein, the majority having a NW-SE trend. They are marked by lines of waste hillocks and there are few exposures, but most seem to be wrench faults with only minor displacement. There are also some NE-SW veins which may be tension gashes.

Across the northern end of the Gulf, old mine maps show Gang Vein splitting into WNW and WSW veins. According to Flindall (1982), the southerly branch, Jackson Grove, is aligned with Slack Rake to the west of the Gulf Fault (the Barmaster's map does not show an extension and Rieuwerts (*pers. comm.*) is also doubtful about the position of Slack Rake). However, a vein continues through Samuel Mine before curving somewhat to the southwest. Both the Geological Survey (Frost & Smart, 1979) and Flindall (1982) regarded this WSW branch as the continuation of the

Gang Vein, the former indicated it as a minor fault downthrowing south. However, just inside the entrance to the Middleton Limestone Mine a WNW-ESE vein, sub-parallel to the entrance drive, has been regarded by the mine company as the Gang Vein. It is aligned with the northern (Gang Vein) branch across the Gulf. Regrettably there are no exposures of this critical section of either the Gang Vein or its WSW branch where they intersect the Gulf Fault, owing to quarry buildings and waste. Further into the limestone mine, the Gang Vein is a fault downthrowing 10 m to the south. Three other sub-parallel WNW-ESE faults have been intersected by the limestone mine: they have downthrows of 36, 21 and 30 m to the south. These faults all show patchy mineralization and localised old lead mine workings. One old mine level encountered recently (early 2005) lies along a fault which shows vertical slickensides at one point and horizontal slickensides at another, clearly showing two phases of movement (Paul Deakin, *pers. comm.*). The faults are difficult to relate to E-W and NW-SE veins on the surface and were not recognized there by the Geological Survey. The discrepancy may be due to some form of offsetting where the fractures pass through the lava.

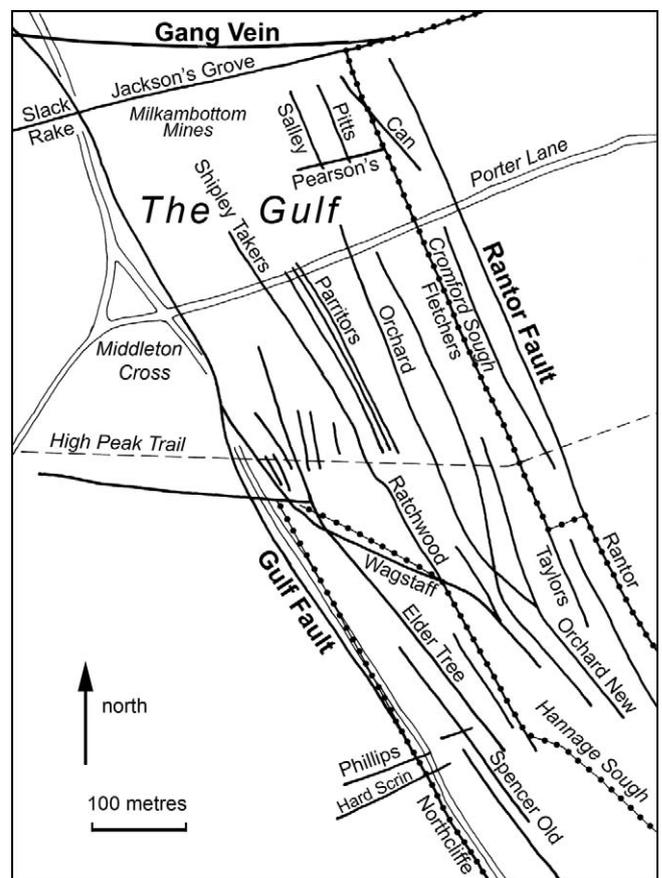


Figure 2. Sketch map of mineral veins in the Gulf (based on a compilation by Flindall, 1982).

The Gulf Fault

Bounded by the Gulf and Rantor Faults, the Gulf (Gulph in many old mining documents) forms a small graben with a NW-SE trend north of Wirksworth town. About 300 m wide it has several mineral veins along its length, parallel to the bounding faults: these may be step faults but no evidence is available. Southeast of the High Peak Trail (former mineral railway) the Gulf is floored by Edale Shales between the two limestone fault scarps, but the shales are entirely obscured by mine waste heaps. Much of the upfaulted western fault scarp has been quarried away in the Middlepeak and adjacent quarries. How far north of the Trail the shales extend is uncertain: their outcrop could "feather out" close to Middleton Cross or it could extend a few hundred metres further north – buildings and quarry waste obscure the area. .

The topographic contrast between the shale-floored Gulf and the up-faulted limestone masses led Shirley (1959) to regard it as a geologically young, post-mineralization structure, but in fact both the bounding faults are mineralized, the Northcliffe Vein following part of the Gulf Fault, and the Rantor Vein along the fault of the same name (Fig.2). The nature and throw of both faults is uncertain. Most geological reports give no amount for the downthrow on either fault, as no single stratigraphic horizon is visible on both sides. From estimates based on the probable position of the shale/limestone boundary on each side, the Gulf Fault has an average downthrow of around 150 m to the northeast. This is confirmed by Carruthers & Strahan's (1923) figure (quoted from Farey, 1811) of 486 feet (148 m) downthrow NE at Twentylands Mine towards the southern end of the Gulf. A section across the Gulf drawn by John Wheatcroft in 1831 also shows a downthrow of about 480 feet (146 m) measured between a "Great Clay" (= Lower Lava) occurring on both sides. It is uncertain how he determined this, as the Lower Lava is not present in Middlepeak Quarry west of the Gulf Fault; he did not show any Rantor Fault. Towards the southern end of the Gulf, at depth in Meerbrook Sough, the soughers' agent's reports indicate that the Gulf Fault was a shatter zone about 50

feet (15 m) wide with several fractures in a fault breccia of limestone, mineral matter, shale and water-worn limestone boulders (the latter suggest some form of karstic development, but no other data is available). Further north, near Middleton, the Matlock Lower Lava outcrops above the Middleton Limestone Mine entrance and is known in lead mines at depths of more than 100 m nearby, indicating a total throw of around 120-130 m down to the northeast.

In Via Gellia to the north of Middleton, the Gulf Fault seems to be dying out as it only displaces the Lower Lava by about 70 m down to the northeast. In Goodluck Mine in Via Gellia, the Gulf Fault was claimed to have been identified (Amner & Naylor, 1973), though the displacement was minimal and there was only minor mineralization.

The course of the Gulf Fault is along or close to the Wirksworth to Middleton road (B5023) - renewed movement might be a case of "tear along the dotted line". A small section of a fault plane, which may be either the Gulf Fault or a split off it, is visible at the road side near Middlepeak Quarry entrance: it dips steeply northeast towards the Gulf. A similar hade can be inferred from the fault's position along the road to where Twentylands Mine worked Northcliffe Vein, some 180 m east of the surface trace. At depth in Twentylands Mine the Gulf Fault was also found in Meerbrook Sough. Old plans show Northcliffe Vein as though it was nearly vertical, as is usual with most mineral veins, but clearly the fault has a distinct hade to the northeast, and this suggests normal faulting along the southwest side of the Gulf.

The workings of the Ratchwood Founder Mine (Warriner & Birkett, 1982) passed through the position of the Gulf Fault near Middlepeak Mine but only a simple nearly vertical fracture in the limestone was recorded by them. Several similarly vertical fractures in that mine mark the positions of veins within the Gulf. Otherwise no evidence is available of either normal or wrench directions of movement.

The Rantor Fault bounds the northeast side of the Gulf, with a displacement of around 50 m down to the southwest. The nearly vertical appearance of the fault

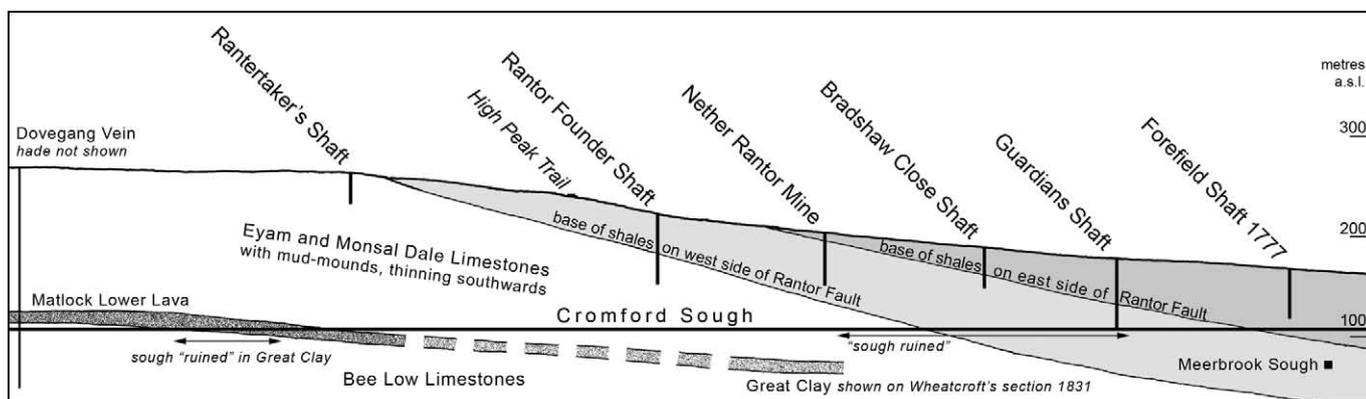


Figure 3. Section along Cromford Sough, following the Fletcher and Rantor Veins (compiled by J. Rieuwerts).

scarp at Raventor (= Rantor) and the presence of the Rantor Vein along it suggest that there is a dextral wrench sense of movement with the shale/limestone boundary displaced laterally. Rieuwerts (1980, 1981) has been able to construct a section along the Rantor Fault with the base of the Cawdor (=Eyam) Shales on each side (Fig. 3): this indicates that the downthrow may approach 100 m down to the southwest at the southern end of the Gulf. The branch of Cromford Sough driven southeast along the Rantor Fault was later “ruined” where it was in the shales. A branch of Meerbrook Sough driven northwest some 30 m beneath the latter also had problems in a “Great Clay (the Lower Lava). In the other direction, to the northwest of Middleton Cross, the Rantor Fault appears to die out leaving the Gulf structure as a half-graben. Still further northwest, the Rantor Fault was not recognized in Via Gellia.

The Gulf and Rantor Faults appear to be cut off by an eastern extension of the Yokecliffe Fault just south of Wirksworth; this has an east west trend with a downthrow to the south. Consequently, the Gulf structure cannot be recognized in the Millstone Grit country further south.

Discussion

The presence of horizontal slickensides on part of the Gang Vein and the lack of displacement where it crosses the Gulf Fault is anomalous at first sight, but in a vein dominated by calcite fill the horizontal movement required to produce horizontal slickensides may have been small. As noted above, one of the faults in the Middleton Limestone Mine shows evidence of both normal (vertical) and wrench (lateral) movement within a few metres. Also, if the Gang Vein is in fact a series of en echelon fractures, as its sinuous course and offset suggest, the lateral movement shown at its eastern end may not be present throughout the system. Quirk (1993) argued that the direction of the stress field changed through late Dinantian to late Westphalian times, and that the fracture/vein system was progressively developed in response to the changing stress pattern from late Dinantian times onwards. In the early phase (late Dinantian) there was no cover of Upper Carboniferous strata, so the depth of burial necessary for the mineralization process had not been attained. However, the limestones were lithified and could be subject to fracturing and folding. The early NE-SW extension in the stress field caused NW-SE fractures to open in the limestone up to the contemporary surface though there is little evidence of displacement. The growth of the Bole Hill anticline resulted in a major E-W fracture – the Gang Vein. Mineralization was later, as the process required a cover of 1500-2000 m of Millstone Grit and Coal Measures. Thus mineral emplacement mostly dated from late Westphalian times, when the hydrothermal mineralizing fluids utilized re-opened earlier fractures to form the vein system (Plant & Jones, 1989). Together these arguments demonstrate the polyphase

nature of movement on the fracture/vein system. The sequence of events may therefore be as in Table 2.

Conclusions

From the limited field and underground evidence available, it is clear that there has been polyphase movement on most faults and veins from late Dinantian to late Westphalian times. The apparent anomaly of the intersection of the E-W Gang Vein with its wrench movement with the NW-SE Gulf Fault can be explained by the former being initially a normal fault system meeting the similarly normal Gulf Fault hading at an angle of about 45°. Later, post-mineralization wrench movement of the Gang Vein, shown by horizontal grooving in its Godbehere vein section, allowed it to cross the Gulf Fault without lateral displacement; its extension continued to the WNW through the Middleton Limestone Mine. Subparallel faults also occur in this mine. A WSW branch, Jackson Grove, also crosses the Gulf Fault and continues towards Samuel Mine.

1. Initial folding of the Bole Hill anticline was accompanied by NW-SE fracturing of the limestone surface in latest Dinantian times. The Gang Vein can be visualized either as a single east-west normal fault or possibly an en echelon series of faults, with a net downthrow to the south.
2. Deposition of the Millstone Grit and Coal Measures, gave a cover of 1500 – 2000 m of clastic sediments on top of the limestone. Burial to similar depths in adjacent basins gave rise to hydrothermal fluids which migrated into the limestone massif.
3. Renewed faulting with a NW-SE extensional stress field tended to give wrench movement on NW-SE fractures during late Westphalian times, but movement on the bounding faults of the Gulf was normal faulting, which did not give any lateral displacement of the Gang Vein, but resulted in Upper Carboniferous strata (Edale Shales) being down-faulted into the Gulf graben.
4. Mineralization in late Westphalian times resulted in the mineral suite being deposited in the re-opened faults.
5. Later, dextral, wrench movement, particularly on the Godbehere section of Gang Vein resulted in horizontally grooved walls of mineral fill and displacement of the shale/limestone boundary. The Gang Vein apparently crossed the Gulf Fault then without lateral displacement.
6. Enhanced folding of the Bole Hill anticline probably gave further wrench movement on many veins during the Variscan orogeny.
7. Erosion of the Upper Carboniferous cover occurred in post-Carboniferous to Pleistocene times.

Table 2. Postulated sequence of tectonic events affecting the Gang Vein and Gulf Fault.

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