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PART II

Industrial Archeology

The Dorothea Quarry is a large and complex site, presenting many problems to the industrial archeologist. During the course of development of the open pits, new workings destroyed much of the previous working areas. In addition, a large portion of the older quarrying remains have been buried by debris arising from the development of the northern sector of the site, after 1935. The workings are now flooded to within 10 yds. of the ground level and the surface remains are becoming increasingly ruinous. The following discussion of the development of the site is based upon Ordnance maps, quarry engineers' records, verbal evidence of surviving employees, and the author's photographic collection. The figures and other illustrations referred to in the text are to be found in the portfolio accompanying this volume.

Location and Site

Figure 1 shows the location of the Dorothea Quarry within the Nantlle valley, which is situated seven miles south of the former slate-shipping port of Caernarfon, Gwynedd. The most important of the 29 quarries in the district lie to the north of the River Llyfnwy, and the central sector contains a high density of workings. This area, between the villages of Tal-y-sarn and Nantlle, is illustrated in Figure 2, with a geological overlay. The Dorothea Quarry occupies a central position on the alluvial valley floor, adjacent to the basin of the Lower Nantlle Lake. The latter had a surface area of some 40 acres, and although it served as a useful dumping ground for slate waste, the lake waters posed a continuous threat to the low-lying quarries, and several were flooded on more than one occasion. Thus, the lake was drained in 1893-5 by cutting a new, deep river channel.

The Dorothea site, bounding the north-western shore of the lake, consisted of 29 acres of gently-sloping meadow, with one steep outcrop of rock at the north-eastern corner; the latter was the site of the first trial cutting. This land was part of Tal-y-sarn Uchaf Farm, and details of the subdivision of the agricultural land owned by the Pant-du estate, into quarrying liberties are given in Part IIIA.

Geology

The following account is based on the definitive survey by Professor W.G.Fearnsides and Mr T.O.Morris, in 1926[1]. They classified the Nantlle slate beds as Lower-Middle Cambrian strata, which could be directly correlated with the slate beds at the Dinorwic Quarry, Llanberis, and the Penrhyn Quarry, Bethesda. Figure 2 overlay[2] shows the surface geological structure of the central Nantlle area. The principal feature is the high degree of faulting, dividing the strata into 'fault blocks'. These faults have a hierarchy, ranging from major traverse faults, which dislocate the total structure, to strike-faults ("slonts"); the latter generally run south-west to north-east, dividing the beds into smaller 'strike blocks'. Other faults cut the strata at varying angles, and these also vary in scale. Quarrymen recognise these cross-faults as "cefnau" and "pefals", and their frequency have an important effect upon the ease of extraction of blocks on the one hand, and the economic value of the rock on the other.

The original Dorothea liberty contains portions of two broad slate beds, the striped-blue (some 100 yds. wide) and purple (about 170 yds. wide), separated by a grit formation. A large dolerite dyke runs due east-west along the centre-line. Thus the slate beds are divided into four blocks, with a separate pit (A,B,C,D) in each. Although the cross-section (Figure 3) shows a complex structure, conditions at Dorothea were much more favourable than in the area to the north-west. The western boundary of the liberty corresponds with an important line of geological dislocation, the Middle Longitudinal Fault. To the west, the rock is shuffled into numerous disjointed 'strike-blocks', but the beds at Dorothea are more regular, albeit containing several faults. Stratiographically, the striped-blue slate overlies the grit, which rests on the purple slate, but folding of the strata, followed by erosion has led to the illusion on Figure 2 overlay of two beds running in parallel. Reference to the cross-section (Figure 3) shows that the purple is exposed on the western portion of the liberty, where the overlying blue slate has been eroded, and east of the central grit body, the blue slate is underlaid by the purple.

In longitudinal section (south-west to north-east), the whole structure would be seen to dip north-eastwards in a series of folds. This can be illustrated by considering the central grit body, lying between the slate beds. In the northern portion of the liberty (between Dorothea pits A and D) the grit is a massive folded structure, some 30 yds. wide at the surface. The upper portion fills a synclinal

fold, some 30 yds. deep, but with increased depth, the body narrows rapidly as it dips steeply in a slide-fault (where the grit has been rolled and drawn out by the sliding of the strata along the fault face). This massive 'cap', which seriously hampered the development of the northern sector of the quarry, is not present in the southern sector, between pits B and C, where only the lower portion of the body is visible. Here, the 'cap' has been removed by erosion, thus proving the north-eastwards dip of strata.

Having dealt with the general structure, the individual beds may now be examined in more detail. Each of the slate beds is divided into a number of veins, having differing characteristics and economic value, and the beds are also divided into 'strike-blocks' by fault lines. The material in each strike-block form anticlinal structures (the fault representing the syncline), and the significance of this is that during the process of folding, the strata was continuously upfolded, such that none of the slate was carried down deeper than about 600ft. below the present land surface, i.e. all the reserves lay within the limits of open-cast quarrying. The cleavage plane runs south-west to north-east, and is nearly vertical. Thus, it cuts through the old bedding planes at varying angles near the crown of the anticlines.

W. J. Griffiths, Dorothea manager from 1900-35 and a respected geologist, recognised ten divisions of the striped-blue slate bed and seven in the purple slate. These are described in a geological cross-section drawn in 1901 and revised in 1914[3]. Commencing with the blue, the top vein

was the Upper Striped Vein ("Llygad Gwythiennog Uchaf"), 75 yds. thick. The topmost layers immediately below the overlying grit was full of green slate bands, some more than a yard thick. The presence of these green stripes was deleterious on two counts. Firstly, some were of gritty material, and would not split, whilst others were so weak as to cause large rockfalls. Secondly, any blemish such as stripes or spots relegated the finished roofing slate to second quality (with a reduced market value), regardless of grading according to thickness (usually the primary criterion).

The second division was the Great Bed ("y Llygad Mawr"), 15 yds. thick, and containing dark mauve or violet rock yielding thin, smooth slates of excellent quality. Under this lay 10 yds. of highly striped rock, 30 yds. of clear slate and 15 yds. of greenish-grey rock which could only be worked as slabs. At the base of the bad vein there is a yard thick green stripe, marking the top of a 60 yd.-thick rock body discovered at the opening of Quarry B, c.1841. This is termed "the Old Vein of Gwll Fire" by W.J. Griffiths, but the remainder of the body, down to the grit, is termed the Lower Striped Vein by Fearnsides and Morris. Under the Old Vein was a 10 yd.-thick Bad Vein, followed by the 18 yd.-Half-clean Vein and 9 yd.-"Lower Llwyd" (grey slate). The base of the blue bed was a clean slate vein exposed in the Quarry B Floor VII 'sink', opened in 1906; its thickness was estimated at 40 yds.

The grit underlying the blue slate varies in thickness from 40 yds. at the surface, to only a few inches at Floor IX, Quarry C, some 500 ft. below ground level. Underlying the grit is the Upper Striped Vein of the purple slate group. This is 40 yds. thick, and is almost identical to the striped blue veins at the top, but the colour changes to red further down. The base is marked by a prominent 6 ins. thick white

("y wythien wen"), which is an important indicator to the quarryman. Under this is 15 yds. of red slate containing an abundance of yellow-green spots (the Red Spotted Vein); these blemishes decrease the market value of the produce. The next vein, the Slight Purple ("y Glas-goch") was the most productive source of raw-material in the valley. At Dorothea it is 80 yds. thick, and of the highest commercial value; this was the main deposit discovered and exploited at Quarry C. Below this was the 15 yd.-thick purple vein, underlying a double white stripe, which demarcated the base of the Slight Purple vein. Then came the "Great Stripes" (30 yds.), followed by red slate (10 yds.) underlaid by a white stripe. This marked the top of the 70 yds. thick New Vein ("y Llygad Newydd"), which was the main body worked at Quarry E. The last division (not uncovered at Dorothea, and thus not recognised by W.J.Griffiths) was a rough Green Vein ("y Llwyd Garw"), some 10 yds. thick. Under this is found the Glog grit group, which marks the end of the slate deposits.

The second "purple pit", Quarry D, was a continuation of Quarry C, north of the central dolerite dyke. Further north, Quarry G (acquired in 1932) only reached sufficient depth to work the upper, striped veins. Conversely, due to the north-eastwards dip of the strata, deeper veins were uncovered at Quarry E, situated south-west of the main Dorothea workings. On the western side of Quarry E, a strike fault with a throw of 110 yds., brings the Slight Purple Vein to rest alongside the New Vein.

Quarry F is remote from the other pits worked by the Dorothea Company. It lies in a region of complex faulting (Figure 2 overlay; Figure 4) and the rock is spoilt by a high density of minor cross-faults ("pefals"), which reduced the slate-making yield to an unecomomic level. The main rock body worked at Quarry F was the purple bed. The striped blue was left unworked because of the cost of removing the large overlying grit bed (see Figure 4), and the reduced market value of that material during the main quarrying period, in the early twentieth century. The mottled-blue slate bed had been extensively worked by other companies in the nineteenth century, and no attempt was made by the Dorothea Company to reopen the old flooded quarries.

General Description of the Development of the Dorothea Quarry

The present form of the Dorothea workings is very different from their appearance in the nineteenth century. Figure 5 shows the expansion in surface area of the workings (obtained from Ordnance maps), extrapolated in Figures 6 and 7 to show the approximate development in vertical profile. The choice of dates was dictated by the available primary material, viz, an oil-painting dated c.1860[4]; Ordnance surveys (25"= 1 mile), 1888, 1899, 1913; and photographs 1896-1970[5]. The profiles were constructed by extrapolation from a geological cross-section[6], showing developments from 1901-14. Additional information was obtained from scattered references amongst other quarry documents, and in Figures 6 and 7, profiles are only approximate, the important factor being the trends illustrated.

Due to the partition of the slate beds into four distinct geological sectors within the original Dorothea liberty, four separate pits were sunk, viz :-

blue slate - Quarry A (c.1823), and Quarry B (opened in two stages, c.1834 and 1841)
purple slate - Quarry C (c.1843), and Quarry D (c.1861).

Each remained a distinct unit until the 1890s, when removal of bad-rock partitions commenced. From the date of commencement to 1888, the surface area of each pit increased quickly, matched by a steady increase in depth. After 1884 the quarry suffered a series of hugh landslides due to insufficient clearing of top-heavy overburden, but a concerted attempt to overtake the arrears in such work was not commenced until J.J. Evans resumed his old position as quarry manager, in 1894. His policies were retained by his successor, and the work is illustrated by the periods 1889-99 and 1900-13 on the figures.

Quarry A was closed in 1902, and B nominally closed in 1908; however, reference to Figure 6 shows that a body of purple rock under Floor VI Quarry B was pursued from Floors VII-IX, Quarry C, until 1945. The major work done in the post-1913 period was the development of Quarry D, and its amalgamation with Quarry G (acquired in 1932). The debris from this project was tipped into Quarries A and B (after 1935) and into C, post-1945.

The position at Quarry E is complex, due to several exchanges of land between the Dorothea and South Dorothea Quarry Companies. Details are given in Part IIIA, but a brief outline is necessary to explain the development trends. The two areas of quarrying pre-1899 were two entirely separate concerns. The larger, on the western side, was owned by the South Dorothea Slate Quarry Co Ltd, whilst the smaller was Quarry E, Dorothea, opened in 1891. In 1903 the boundary was altered, such that the southern half of Quarry E was transferred to the South Dorothea Company (see boundary line on Figure 20). From 1903-1921, the latter's two pits (main and small) expanded eastwards; this is illustrated on Figures 5 and 7 by the period 1900-13. However, in 1921, the Dorothea Company purchased the assets of the South Dorothea Company, and the whole pit became known as Quarry E. The eastwards development continued in the main pit only, until 1953; the small southern pit was abandoned c.1935.

The trend of development of surface features is shown on Figure 8. The figure illustrates the general tipping trend in the twentieth century, and many of the features did not exist at the same date. The overlay shows the tips in 1888. At that date, most of the tipping was low-level, but two second-level tips had been established c.1880. The southern boundary, being the parish boundary (along the mid-line of the Lower Nantlle Lake), had been reached with some encroachment visible. After 1890, the tipping liberty was extended south-eastwards,

and the development of the second-level tips is prominant. After 1935, much debris was deposited directly into abandoned workings, and after 1945 the only surface tipping was that at Tal-y-sarn Hall, in the north-western sector.

Having identified the general pattern of development, details of the growth of the individual pits can now be discussed, commencing with Quarry A, and using the appended maps and key to the important buildings on the site.

Quarry A (Twll Uchaf).

This has been known under a variety of titles. This was the original Cloddfa Turner (i.e., William Turner's quarry), and became 'yr Hen Dwll' (the Old Quarry) after its abandonment c.1834; officially, its title was Pit No.1. After its reopening, c.1860, the pit was colloquially known as Twll Uchaf (the Upper Pit), whilst the new official designation (which is maintained in this thesis) was Quarry A.

Quarry A is the oldest excavation on the property, and its location is shown in Figures 2 and 5. When Messrs. Turner and Morgan became lessees of the site c.1828, there was a small disused quarry somewhere within the area of the present Quarry A. Its exact location is not known, but it is described as an excavation served by an open cutting[7]; this, and other factors in its later history, leads to the conclusion that the old quarry lay south-east of the present centre of Quarry A, where the land-surface dipped steeply southwards. The site may have

had an exposure of the striped-blue slate, upon which a trial quarry was commenced, or alternatively the existence of the vein may have been deduced from the trend of the strata at the old Pen-y-bryn Quarry, a few hundred yards to the north-east.

A nineteenth century description of the first Dorothea workings infers that the original cutting was at a lower level than the Nantlle Tramway (opened in 1828), and that Messrs. Turner and Morgan established a new quarry bank on a higher level, to gain a direct link with the outlet tramway[8]. The pit was worked for 5 years, and would therefore not have been more than two floors deep (say, 50 yds. total). The slate on the north and eastern sides appears to have been too hard for the contemporary slatemakers, and that to the west had about 15 yds. of sandy overburden. Thus, the quarry developed predominantly southwards until a large body of bad-rock was uncovered c.1834. The bad-rock was a large dolerite dyke, which cuts east-west across all the strata within the Dorothea property. The management erroneously surmised that the terminal boundary of the slate vein had been reached, and therefore preparations were commenced for untopping the slate on the western side of the quarry. The scheme was novel in that the debris was to be transported to the tipping site in the Lower Nantlle Lake by canal. The distance from the quarry to the lake was about 120 yds., and construction of the canal was commenced at the lake-side, using a raft (with a 15 ton payload) to carry the debris. However, a short distance along the route, the striped-blue slate vein was unexpectedly

re-discovered. The slatemaking quality of this new deposit was of such a high standard that the development of Quarry A was shelved, and that pit abandoned in favour of opening a new pit, No 2, or "Twll-y-weirglodd" (part of the later Quarry B)[9].

Quarry A remained idle from c.1834 to the late 1850s. In March 1858 the shareholders of the Dorothea Slate Company approved a scheme to reopen the "old pit" and to construct a water-balance, to raise material from that quarry[10], and c.1860 a powerful steam winding engine was transferred from Quarry B to Quarry A[11]. Unfortunately, there are no statistics available for the individual Dorothea pits before 1880, and thus the history of Quarry A from 1860-80 is uncertain. However, it is known that a large landslide occurred in the early 1870s; this was from the grit body at the north-western corner of the pit (next to the old Commercial Inn), and much of the bottom of the pit was buried[12]. Very little of the debris appears to have been cleared until the late 1870s, probably because there was little prospect of sufficient production to justify such expenditure until the Nantlle Tramway was diverted. The track was only a few yards from the northern edge of the pit, by the 1870s, and the development of the latter (to follow the slate bed north-eastwards) was arrested. One of the first priorities of O.T.Owen, on becoming quarry manager in January 1875, was the restoration of Quarry A, and this was achieved by moving the Nantlle Tramway to the quarry boundary, as shown in Figure 12, overlay 1[13]. However, by 1882 Quarry A had expanded so rapidly that even the diverted tramway was in danger of being undermined, for the second time. Thus,

in November 1882 the London and North Western Railway Company was forced to issue a notice restraining the Dorothea Company from working any further in a northward direction[14]. The problem was resolved by diverting both the tramway and the parish road northwards onto a portion of the Pant-du estate outside the Dorothea boundary (Figure 12). This involved the lessees of the Gallt-y-fedw Quarry giving up one small pit (which was subsequently in-filled with debris for the tramway route) and the Dorothea Company gained a small area outside the original liberty. The negotiations, which must have involved both quarry Companies, the landlord and the LNWR Company, were prolonged, and the scheme was not completed until 1886. Unfortunately, little correspondence survives, and it is impossible to estimate the cost, which must have been borne by the Dorothea Company[15].

A large body of rock became available with the removal of the Nantlle Tramway, and the increase in surface area of the quarry can be seen in Figure 5. The gross profit of the pit (value of produce, or 'make', minus wages) from 1887-91 ranged from £3,600-£9,000 per annum, compared with a mean of £3,500 in 1881-4. The fluctuations appear to have been due to changes in the market value of the 'make'[16], probably related to the frequency of green stripes in the rock body; these occurred in swarms, and greatly reduced the value of the slate on purely aesthetic grounds. Unfortunately, the massive granite dyke, which separated quarries A and B, became top-heavy, and the management pursued a policy of minimal expenditure on un-remunerative quarrying operations. Thus, in January 1891, a large portion of the dyke near the centre of the

Dorothea complex, became unstable, and several hundred thousand tons of worthless material collapsed into the pits. At Quarry A, the south-western corner collapsed from the surface down to about Floor II level (some 50 yds), burying most of the bottom of the pit. No attempt was made to clear the bottom because quarries B and C were given a priority of the limited funds available, and due to the possibility of further landslides at Quarry A, which was very narrow and deep (approximately 100 yds. x 100 yds. x 90-100 yds. deep). Sufficient debris was removed to enable nine 'bargains' (productive units) to continue working, but three of these were abandoned in January 1894 because of a threat of further 'falls'. This resulted in the annual gross profit falling under £2,000, and by 1898 the slatemaking yield was only 7 per cent, compared with 25-30 per cent at Quarries B, C and E: the ratio of 'make' to total excavated material at Quarry A was 1:99, compared with 1:20 elsewhere. The output of Quarry A averaged under 1,000 tons ('make') per annum, in the late nineteenth century, and continued to run down after 1900. Only two 'bargains' (6 men) were at work when quarrying was suspended, in March 1902. They were working on the northern face of the pit, and it was feared that the parish road would be undermined; the last diversion of the road (and tramway) had been completed c.1901, avoiding an impending collapse[17].

Work restarted on the northern face of Quarry A in March 1936. The parish road had been closed in 1927, and the land became the freehold possession of the Dorothea Company in 1932. A crew of four rockmen and four labourers opened a gallery, some 30 yds. from the surface, but

the place was abandoned in January 1937, probably because of its low profitability[18]. The remainder of Quarry A was designated as tipping ground for the new galleries opened on the upper sector of the eastern face of Quarry D (after 1935), and after c.1946, the mill waste was diverted from the lake tip to the south-eastern corner of this pit. About two-thirds of the pit was filled with debris, but when Dorothea closed, in 1970, there was sufficient tipping room remaining at Quarry A for several years.

Winding Arrangements at Quarry A.

During the first period of working at Quarry A (1829-34), the winding machinery consisted of a number of "whimseys". This apparatus consisted of a wooden drum set on a vertical axle; the drum was positioned about 8 ft. above the ground, and had an attachment for a harness on the under-side. The machine was operated by leading a horse (attached to the harness) in a circular path, thus turning the winding drum; to reverse, the harness had a swivel pin which enabled the horse to be turned in the opposite direction, without the need to un-couple. The hauling gear varied according to circumstances; some whimseys employed a vertical lift, entailing the use of a headstock similar to a ship's crane, and lifting the slate blocks either with chain slings, in skips (called "kibbles"), or employed trams with detachable bodies (to minimise the TARE weight); others were used to haul complete trolleys up short inclined planes hewn out of solid rock[19]. It is not possible to state the number of whimseys at Quarry A in the 1830s, nor the type of hauling gear, but it is probably significant that no inclined planes are visible at the pit in the oil-painting dated c.1860[20].

The shareholders of the Dorothea Slate Company adopted a resolution on 31 May, 1858, whereby a water-balance was to be erected at Quarry A[21]. This was presumably to be an inclined-plane, worked by transporter cars, on the water-balance principle, i.e. the weight of one car carrying a full water-tank was employed to haul another car, carrying a loaded waggon up the incline. For the return journey, the second car, returning an empty waggon to the pit bottom, hauled the first car, with the water-tank emptied, back to the original position. It is uncertain whether this incline was constructed, as it does not appear on the oil-painting referred to above. In addition, a powerful steam winding engine was transferred from Quarry B[22] to work a double (4-carriage) chain-incline (Figure 21). In this apparatus the rail tracks of a conventional incline were replaced by suspension chains, upon which ran two, or two pairs of simple carriages, working in opposition; waggons were attached to winding chains running via the carriages to the winding engine, and the return phase of the winding cycle was under the control of gravity. The engine room can be seen on Figure 11, being the southern half of the large building numbered 2; the northern half is the original quarry manager's house, built c.1835. Reference to the identification list for numbered buildings (preceding the figures in the attached portfolio) will show that the winding engine rooms have been designated according to the official quarry number of the engine (from 1 to 20).

When development of the northern sector of Quarry A commenced, a semi-portable winding engine was erected temporarily, without a building; this probably occurred in 1877, the date of purchase of the machine.

This was still at work in 1888, but was moved to the site of the new Quarry E in 1891, where it was known as Engine No.14. A permanent winder was installed to serve the northern part of Quarry A in 1886 (No.1, Figure 11). The single (2-carriage) chain-incline was powered by an old design, single-eccentric, single-cylinder, horizontal steam engine, purchased second-hand, and used a Cornish-type boiler salvaged from the landslide at Quarry D (1879). After the pit closed, this engine was transferred to Pyramid C as Engine No.13a.

The fourth engine associated with Quarry A was a small single-cylinder horizontal powering the transporter incline A carrying debris up to the second-level tip (No 3, Figure 11). This was installed in 1885, and had formerly been winding at Quarry C[23]. The incline consisted of a solid masonry (slate rubble) ramp carrying two 4 ft. gauge transporters, working in opposition. Each car carried two waggons, and the former were wedge-shaped (when viewed side-on), to keep the loaded waggons level during the journey up the gradient. The incline is pierced by a barrel-vaulted tunnel for the 3 ft.6 ins. gauge outlet tramway. This tunnel was constructed sufficiently wide for 4 ft. 8 ins.standard gauge track, but the headroom is too low for the passage of a locomotive. Thus, if the Nantlle Tramway had been re-gauged (see Part IIIE), horses would have continued to work the Dorothea branch line.

During the temporary reopening of Quarry A, in 1936-7, the working face was served by a ropeway termed "Cableway A" (Figure 12). This was a hybrid chain-incline, using one carriage only, and the main cable

was mounted on wooden masts, as per Blondin cableways. The plant operated in the same manner as a chain-incline, with an arrestor (or "catcher") mechanism on the main mast enabling the waggons to be landed on the Quarry A bank. Cableway A was powered by engine No 3a, on Pyramid B, and the relative locations of the engine room and masts required the winding rope to change direction three times[24].

Pumping Arrangements at Quarry A

The water-table at Dorothea is within 10 yds. of the land surface. Thus, even the first 'sink' (Floor I) required pumping. Initially, hand-worked pumps would have sufficed[25], but by the early 1830s Floor II would have been opened, and more powerful equipment was required. Thus, a water-wheel was installed, working a bucket (or "lift") pump[26]. When Quarry A was abandoned, c.1834, pumping was discontinued, and it is probable that the reciprocating "sweep-rods" from the water-wheel crank were re-routed to serve the new Pit No 2 (later part of Quarry B).

By 1851, Quarry B had its own wheel (termed the "Lower Water-wheel"), and a replacement was planned, with the original lower wheel being destined to be transferred "to the site of the upper wheel". No reason is given, and one can only speculate that the old "upper" wheel was unservicable by this date. The resolution was re-affirmed on 30 January, 1855, showing that the work had not been carried out immediately[27], but Quarry A was reopened c.1860, probably using the "new" wheel for pumping. This is shown on Figures 11 and 12, overlay 1. It was 28 ft. diameter, and probably overshot. In times of drought, winding engine No 2 could be connected to the pumps, but the water-wheel

was preferred because of the economy afforded. The general water supply system can be seen on Figures 11, 12 and 19, but it appears that the course of the wooden launders was modified on several occasions. By 1894 the Quarry A pumps were a three-stage arrangement of 11 ins. diameter bucket-pumps[28]; they were superseded by the Quarry C Cornish pumps in 1906.

Quarry A Bank

This is shown in Figure 8 (small scale) and Figures 11 and 12 (large scale). The buildings associated with Quarry A were:-

No.1 - Engine No.1 room, 1886

No.2 - Original quarry manager's house (northern half) built c.1835 with Engine room No.2 added c.1860; the latter was demolished in the 1960s

No.3 - Engine room No.3 on top of Incline A, constructed in 1884-5

Slab mill (Figure 11 overlay) - Built in the early 1840s to make use of a vein of hard grey slate at Pit No.2, this mill contained two saws and two planing machines, worked by the 28 ft. diameter "Middle Water-wheel"[29].

Quarry B (Twll Fire)

This was originally two separate quarries - 'No.2', "Twll-y-Weirglodd" (the Meadow pit), and No.3, "Twll Fire" (named after the installation of the first steam, or "fire" engine, c.1843). By the 1860s, both pits had been amalgamated into one quarry, designated Quarry B. The circumstances relating to the discovery of the striped blue slate vein at Pit No.2 have been recorded in the account of the development of Quarry A. Pit No.2 is reputed to have been one of the most

productive ever worked in the Nantlle valley, having only a very thin layer of clay overburden, and almost no worthless top-rock. The slate was also of exceptional quality, with workable blocks being the sole material raised for days on end. However, this situation only lasted for about six years, and by 1840, a hard gritty vein had been uncovered at the southern end of the quarry. This grey slate was worthless for making roofing slate, albeit excellent for manufacturing slabs, and the prognosis appeared serious after a trial shaft was sunk 10 yds. into this vein, without breaking through into the underlying strata. Because the veins dip north-eastwards, it was obvious that this grey vein underlay the whole of Pit No. 2. Conversely, it was perceived that a new trial shaft sunk in the meadow south-west of that pit would uncover the underlying strata more readily than continuing the shaft at the bottom of the pit. The new shaft was sunk close to the margin of the Lower Nantlle Lake, and the result was very promising.

The lower portion of the striped-blue slate bed was uncovered in the meadow by the lake-side, and from the dip of the strata it was known that this rock extended under Pit No. 2. A new quarry (Pit No. 3) was opened, and the output was so prolific that a steam engine was purchased c.1843 with a chain-incline, the first at Dorothea. Pit No 3 was worked north-eastwards towards No 2, and the grey slate vein (15 yds. thick) was progressively stripped away; within a relatively short period the dividing land between the two pits had been removed, and both were collectively termed 'Quarry B' by the 1860s, when that system of notation was first employed[30].

Quarry B was the most important productive unit of the Dorothea set from the 1850s to the 1880s, but suffered a major setback in December 1884, when a serious landslide filled the bottom with thousands of tons of debris. This was the 'fall' which killed seven men, and caused the whole of the Dorothea system to be flooded for nearly a year (see Part IIIA for details). The annual gross profit of Quarry B in 1880-4 had averaged £8,000-£10,000, and was by far the most profitable sector of the concern. In 1886-90, the figures ranged from £3,700-£8,000, showing a marked recovery by 1889. However, an extremely damaging landslide occurred in January 1891, when a large portion of the granite dyke, on the northern side of the pit, collapsed. Quarries A and C were also affected, but to a lesser degree. On this basis, Quarry C was selected as the first priority, and clearance of debris from Quarry E did not commence until 1896. In the interim, the gross annual profit was reduced to £2,000-£3,000, and after the double-shift work was introduced in September 1896, the increased cost of wages brought the gross profit down to under £1,000 per annum for the next three years. In an effort to produce some slate, and thus pay for the clearance work, a new 'sink' (Floor VI) was opened at the southern end of the pit; this was officially designated B2, whilst the old Floor VI 'sink' (buried by the 'fall') was known as B1. The slatemaking yield in 1898 was 26 per cent (compared with 31 per cent at Quarry C) and the ratio of 'make' to total excavated material 1:35.7 (1:10 at C)[31].

In the 1900s, the 'make' at Quarry B averaged 5,000 tonns per annum from 40 'bargains'. This was only about 1,000 tons less than Quarry C, but several factors militated against Quarry B. Firstly, the amount of rubbish raised from the pit was more than twice that from C (about 10,000 tons per annum, compared with 5,000 tons), and the market value of the slates was lower, due to customers' prejudice against the green stripes therein (resulting in a 25 per cent discount on striped slate in 1907). This was reflected in the gross annual profit, which averaged £4,000 for B, compared with £1,000 at C[32]. The high tonnage of debris at Quarry B can be accounted for by overburden removal on the northern side, and stripping a layer of bad-rock from the bottom of the pit. It is unfortunate that after clearing all the debris and bad-rock, the new 'sink' (Floor VII), commenced in 1907, revealed that the lower portions of the strata were extremely stripey. Production was maintained at Quarry B merely because a profit was being made. However, a tipping dispute (with the landlord) from 1906-08, dictated that the total amount of debris generated at the Dorothea Quarry had to be drastically reduced, and because a 'fall' at Quarry C had increased the total tonnage of debris, production was stopped at B in August 1908[33].

Winding Arrangements at Quarry B.

Quarry B was originally served by horse-whimseys, but a rotative condensing beam-engine was installed at the old Pit No 3, c.1843. The engine (No.9, Figure 10 overlay) worked a single (two-carriage) chain-incline, the first use of this apparatus at Dorothea. The number of chains (and carriages) was increased to four at a later date, and by

the 1890s an additional two-carriage unit had been added. The second steam engine was of a similar type, and was purchased in 1853. It worked an incline plane serving the old Pit No. 2 (see Figure 11 overlay). The incline was fitted with water-balance apparatus in 1857, as an economy measure, and by c.1861-2 the engine had been moved to serve Quarry A[34].

Debris raised by engine No 9 was carried up to a second-level tip using transporter cars on Incline B (see Figure 10 overlay). This incline was constructed c.1880, probably using an existing intermediate-level tip, derived from Quarry C as a base. The transporter cars were wound up the incline by a semi-portable double-cylinder steam engine (No.13, Figure 10 overlay).

Several changes occurred in the 1890s. Incline B was extended below the Office bank, to carry debris from the untopping of the grit partition between Quarries B and C. In 1897 the transporter incline ceased operating, and the winding engine was connected to a new chain-incline (two-carriage), using a very long wire-rope. In 1914, this engine was transferred to the new Pyramid C engine room (No.13a, Figure 10), and the old house was converted into a locomotive shed[35].

The eastern sector of Quarry B was supplied with winding machinery in 1881. A 60 ft.high pedestal (termed Pyramid B) was constructed near the edge of the pit, as a base for chain-inclines on a new second-level tip (see Figures 8 and 11). The structure shows signs of

modification to the original design during the construction period. As built, Pyramid B was fitted with two single (two-carriage) chain inclines in 1881, each powered by a new twin-cylinder steam engine (Nos. 4 and 5) housed in a common engine room (No. 4, Figure 11). A third chain-incline, serving overburden-removal workings on the north side of Quarry B, was installed in 1899. This was powered by a second-hand single-cylinder steam engine, No. 3a[36].

After the closure of Quarry B in 1908, engines 3a and 4 remained at work. The former continued to raise debris from the overburden removal scheme, clearing the top-rock between Quarries A, B, C and D until c.1935 (Figures 5-7). From March 1936 to January 1937 the engine worked Cableway A (see Figure 12), at the north-eastern corner of Quarry A, and from 1941-45 the engine, in conjunction with No 4, served the new Floor IX 'sink' at Quarry C (illustrated in Figure 11). In the interim, engine 4 was winding from Quarry D (see sub-section on Quarry D below). Engine No 5 was removed in 1923, and set up on the Quarry C second-level tip, winding from Quarry E (No. 5, Figure 10)[37].

Pumping Arrangements at Quarry B

No details are available of the pumping arrangement pre-1860, but it is possible that the pump at the new Pit No. 2 (1834) was powered by the Quarry A 'Upper Water-wheel'. By 1851 another wheel had been erected, probably at Pit No. 3. On 21 January, 1851, a proposal to replace the second (or 'Lower') water-wheel was deferred, but the resolution was adopted at a subsequent shareholders' meeting on 3 February, 1852.

However, the same resolution appears on the Minutes of the meeting held on 30 January, 1855, proving that the work had not been carried out. In 1860, the Lower Water-wheel was definitely pumping the southern, and deepest part, of Quarry B (corresponding to the old Pit No 3). By March 1885 the wheel had been moved to a new site further west because of the expansion of the surface area of the pit.

At its last site, the plant probably consisted of a 35 ft. diameter pitch-back wooden wheel, connected to a two-stage bucket-pump (or 'lift' pump) via wooden flat-rods and two V-bobs. The lower two stages of the pump set were worked by the steam winding-engine No 9. The wheel was supplied by wooden launders leading from the tail-race of the Middle Water-wheel (Slab Mill), and circling the southern corner of Quarry B on a purpose-built bank, cut into the tips just below the Office level. The Lower Water-wheel tail-race joined the pump outflow in an adit excavated through the rubbish tips. The original adit followed a tortuous route westwards before turning south, emerging at the outlet of the Lower Nantlle Lake, at Sarn-wyth-ddwr Bridge (Figure 19). This is explained by the necessity to keep on solid ground, along the old lake shore. In the late 1890s the lake was drained, and a new direct adit was excavated, running south from the pump[38].

Quarry B Bank.

This is shown on Figures 8, 10 and 11. The original bank was some 10 yds. below the present Office bank, and is termed the old Floor I bank (Figure 11). It was derived from the first cutting at Pits 2 and 3, and was the same level as the surface of the old Lower Nantlle Lake. This arrangement proved inconvenient because the finished slate from these pits had to be transported by carts up to the loading sidings of the Nantlle Tramway, at the Quarry A bank, which was at a higher level. To alleviate the problem, the chain-incline installed c.1843 (engine No 9) was placed upon a slate-rubble pedestal, 10 yds. high. A new bank was established, and this was quickly united with the existing Quarry A bank. Thus, Pit No 3 was provided with direct access to the Nantlle Tramway. For some reason Pit No 2 continued to use the old Floor I bank as part of the route for raising quarried material. The blocks and debris ascended an inclined plane to that bank, and then the waggons were hauled up a curved ramp to the new slatemaking bank, using horses. This arrangement was still in use c.1860, but had ceased by 1885, by which time most of the Floor I bank had been removed by quarrying[39].

All tipping was conducted south and south-eastwards into the Lower Nantlle Lake, the north-western quarter of which was demised to the Dorothea Company. Quarries B and C shared a common slatemaking bank and tip up to the 1870s. By the mid 1870s the tipping ground was nearly exhausted, and a second layer of debris was deposited upon parts of the Office bank. This is termed 'second-level tipping', and the

general pattern can be seen in Figures 8 and 8 overlay. The first step was a 10 yds. high bank (termed the 'intermediate-level tip'), probably derived from Quarry C. It seems likely that this was used as a base for the construction of Incline B (see above), which carried debris up to a height of some 30 yds. above the Office bank. This incline, plus another, serving Quarry C (termed 'Incline C'), commenced work in 1883, but tipping was confined to Quarry C debris after 1897[40].

On the eastern side of Quarry B, another second-level tip, some 25 yds. high, was commenced in 1881. This was established by constructing a pedestal for chain-inclines at the edge of the pit; this is termed 'Pyramid B' (see above). This second-level tip received the larger share of the debris from Quarry B, and also all the rubble from Quarry A. By 1890, the tipping boundary had been reached yet again, but unfortunately the landowner granted the Dorothea Company tipping rights over part of the disused Pen-y-bryn Quarry tips (east of Dorothea). Yet, this new land had been filled within ten years, and further extensions beyond the original boundary were required (see Part IIIB for details)[41].

Despite the development of second-level tipping, the sawing mills (replacing non-mechanised slatemaking in small huts, or "waliau") were erected on the Office bank. It was necessary to maintain an access for the slatemaking debris to the lake tip on the lower level, and therefore the development of the tip system had to be carefully planned. Comparison of Figures 8 and 8 overlay shows the segregation of specific tipping areas.

The major building on the Office bank is the Large Mill (Figure 13). It originally served Quarry B exclusively, but as the scale of operations diminished at that pit, slatemakers from Quarry C were moved from the old "waliau" to the mill. After 1908, the building was shared by Quarries C and D, as production of striped-blue slate had ceased.

The Large Mill (No. 7, Figure 11) was constructed in four building periods, being extended when the necessary finance was available. The first portion was built in 1882, and consisted of the western gable, four bays (containing 10 saw tables), and a house for a steam engine to drive the plant. This engine (officially numbered 8) was a single-cylinder horizontal ex-winding engine, salvaged from a landslide at Quarry D (see below). In 1884, another six bays were added, with 12 saws according to the records of machinery purchases. The apparent anomaly in the number of saw tables per bay can be explained by the common practice of installing additional saws outside the mill. The drive axle (or 'line-shaft') was extended outside the building, with the bearings supported on slate-rubble pillars, and the drive-belts were encased in wood to prevent slipping in wet weather. A second steam engine (No. 7) was installed in 1886, to drive some of the new saws, because the existing engine had insufficient power. Engine No 7 was a two-cylinder horizontal, and took over the driving of the whole mill in 1898, providing better economy. Engine No. 8 was removed in 1903, being transferred to take over the winding duties of engine No 9, Quarry B.

The penultimate extension of the Large Mill consisted of six bays, roofed c.1898. Eighteen saws had been installed since 1884, and these had worked in the open in the intervening period. A lean-to erected on the southern half of the temporary wooden eastern gable contained one extra saw, making a total of 41 saws. A permanent slate-rubble gable, with an extra bay, had been built by 1911, incorporating the lean-to, but this was un-roofed until the mid 1930s, possibly to reduce the rateable value of the building. In 1911 there was a row of "waliau" extending east from the end gable, but it is unlikely that there were any saws outside the mill at this date[42].

The Large Mill in its completed form consisted of a central sawing room 295 ft. long x 59 ft. wide, orientated with the greater dimension east to west. The building ends in two half-hipped gables which were originally identical in shape. However, the roof on the eastern gable was severely damaged by a gale in the 1930s, and consequently it was rebuilt with a lower gable wall and larger hip. The side walls are composed of masonry pillars supporting the roof trusses, the intervening spaces being filled by wooden partitions, pierced by doors communicating with the slatemaking cabins. The latter are in the form of two lean-to aisles, one on each of the longitudinal walls of the main room. The cabins were separated by wooden partitions, but the latter were removed from the northern row c.1940, producing a long alley. Large doors were inserted in the end-walls, and the northern tramway of the main room was removed, and relaid in the new alley. The slatemakers were moved into the main room, and this arrangement enabled slates and debris to be loaded indoors, regardless

of the weather. On the southern side of the mill, the original cabins were retained, and an external covered alley was constructed.

Although the two-cylinder steam engine had sufficient power to run all 41 saws and 300 ft. of line-shaft, uneven running was experienced at the western end of the mill due to the drag of worn bearings (made worse by the subsidence at the eastern end of the building), and worn-out saw tables. This was tolerated until the 1930s, when a balancing flywheel on a belt-driven countershaft was installed near the western gable. This evened out the motion successfully. The steam engine was scrapped in 1938, and the mill drive divided between two 40 hp. 3-phase AC motors, powered by a generator housed in the Small Mill[43].

The Small Mill (No. 6, Figure 11 and Figure 14) was constructed in three periods, commencing with the five northern bays and engine room, built in 1892-3. By 1900 another four bays had been added, and in the 1930s the final bay and southern masonry gable were added. The main sawing room measured 140 ft. (north to south) x 32 ft. (east-west), and one row of slatemakers' cabins flanked the western longitudinal wall. The maximum number of saws installed was 11, one being outside the northern gable. The plant was driven by a semi-portable twin-cylinder steam engine (No. 6)[44].

The Small Mill had become disused by the 1930s, and consequently the southern half was converted into an engine room. Two 120 hp.

two-cylinder horizontal 'National' diesel-oil engines were installed in 1935 and 1938 respectively. The first powered a 300 cubic-feet-per-minute air compressor, whilst the second worked a 100 KVA 3-phase AC alternator, supplying electric motors in the Large Mill and pumps at Quarries E and G. When the main pump was converted to electricity in 1952, a second alternator was installed. Pumping was confined to out of working hours, and the air-compressor drive was transferred to the new alternator during the night. Mains electricity was installed in 1956 after one engine sheared its crankshaft, and both engines were subsequently sold.

The mill was partly recommissioned in 1938, with workmen being transferred from the closed Quarries E and G mills. Dressing machines were installed in the northern slatemakers' cabins and the mill drive was taken from one of the oil-engines. The old cabins in the southern portion were converted into a fitting shop, with a selection of powered tools, and the carpenters' wood saw-table (formerly sited outside the Large Mill) was placed under cover in the annexe formerly housing the mill engine. Slatemaking ceased in the Small Mill for a second time, in the late 1940s. However, in 1964 the whole building was gutted, and modern electric high-speed saws were installed. A wooden-framed extension was added on the western side, to house the slatemakers away from the loud noise of the new saws. This last building was not securely held down, and was demolished by a gale soon after its erection[45].

Other buildings on the Office bank (Figures 10 and 11) were:

No. 21 - the old Office, known as the "Office Bach" (the small office). This was erected in the early 1840s, and served as the quarry office until the 1860s. It was used in later years by the slate inspectors.

No. 22 - the new quarry Office, built c. 1860.

No. 23 - the workshops, comprising a smithy, iron stores, and carpenters' shop. The smithy was erected in the 1840s, extended in the 1850s, and the other portions added at an unknown date pre-1864.

No. 24 - stores for lubricating oil, nuts and bolts and steam-packing.

No. 25 - stables for four horses owned by the Company.

No. 26 - eating room ("caban"), built in 1907.

No. 27 - loco shed for "Wendy", 1935.

No. 28 - covered loading bay.

No. 29 - weighbridge, 2 ft. gauge, and old weighbridge, 3 ft. 6 ins. gauge.

Quarry C (Twll Coch).

Quarry C (Pit No. 4) was opened c. 1843-4, as a result of an investigation of the meadow west of the new Pit No. 3. A body of red slate was uncovered, accounting for the colloquial name, translated as 'the red pit'. However, this red vein proved to be only a minor constituent of the purple slate group, which underlay the meadow. The majority of the rock-body was blue-purple, but was very blue in colour on the western portion of the vein. The sale circular of 1848 described Quarry C as "a new opening upon a most extensive vein of

excellent slate ... which will, in a short time, be in a state to produce a large quantity[46]."

There are few references to the early history of Quarry C. The first mention of the pit in the Minute book of the Dorothea Slate Company is a resolution, dated 17 September, 1850, stating that the quarry (No. 4) was to be deepened. This was to be achieved by driving a tunnel from the bottom of Pit No. 3 (Quarry B) westwards under Quarry C (probably Floor II level), and then "roofing" vertically up to the bottom of the pit (to Floor I); the shaft would then be opened out to form a 'sink', which would be drained via the new tunnel[47]. The next reference was a resolution adopted on 30 January, 1855, whereby the driving of a tunnel southwards from the pit, and development work in that direction, were to be halted due to uncertainty regarding the granting of a new lease[48]. The lease was obtained in 1857, and presumably the development continued. However, by 1869, the furthest extent of the pit in a southwards direction had been attained as development ceased when a dolerite dyke was uncovered.

The main trend of development of Quarry C after 1860 was north and east (Figures 5 and 6); the depth of the pit also increased, especially after the natural boundaries were reached, by the 1870s. These boundaries were namely dolerite dykes to the north and south, the property boundary to the west, and a vein of grit (separating the purple and striped-blue slate veins) to the east. It is not possible to accurately chart the dates of sinking new floors, but

Quarry C was consistently one floor less than Quarry B until the 1890s, because the former drained into the sump of the latter via adits driven through the dividing grit partition.

In 1901, the main working area at Quarry C was Floor VI, with a 21 yd.-deep 'sink' (Floor VII). The latter had superseded the former by 1912, when a new 22 yd.-deep 'sink' (Floor VIII) was opened[49]. The last 'sink' (Floor IX) was 10 yds. deep and was commenced in 1941; this was 165 yds. below the ground surface, and about 81 yds. below sea-level. Floors VII and VIII enjoyed a longer life than their predecessors because Quarries B and C were amalgamated in the early twentieth century. The pits were separated by a grit partition, from which several major rockfalls had occurred. The removal of the upper portion of this 'post' commenced in 1895, but after the old Quarry B pumps had been removed, c.1907, the work of totally removing the partition started. The progress of the work can be followed on Figure 6. The lower portion of the partition consisted of purple slate, and this was pursued eastwards into the bottom of Quarry B on Floors VII, VIII and IX.

The excellent quality, and high productivity of Quarry C can be gauged from the detailed statistics available after 1880. In terms of gross annual profit (value of 'make' minus wage), it ranked second to Quarry B up to 1891, save for certain years when the former was filled with debris from 'falls'. The amount varied from £5,000-£10,000 per annum (disregarding the exceptional year of 1886, when only £2,000 was obtained, due to clearing debris).

1891 was similar to 1886, but from 1892 onwards, the pit surpassed Quarry B, and yielded £8,000-£13,500 gross profit annually. The output during this period was about 7,000 tons of finished slate ('make') from 37 'bargains' (productive units), with a slatemaking yield of around 30 per cent and an excellent low ratio of make to total excavated material of 1:10; the actual ratio of blocks raised to rubbish raised was about 1:2. As described above, no development work was, or could be, carried out during this period, and the figures quoted relate to 1898, when only production was carried out. However, even in 1908, when clearing rubble from a large landslide had increased the ratio of blocks to rubbish to 1:4, the yield was 28.4 per cent and the overall ratio 1:17.7, substantially better than the standard quoted 1:20 figure[50]. After 1910, the overall ratio returned to about 1:14, and remained thereabouts until a large 'fall' in January 1924 raised the figure to 1:18, and a massive landslide in 1926 raised it again to a high 1:29. The slatemaking yield remained in the 21-27 per cent range, but the last of the debris was not cleared until 1936, when the overall quarrying ratio returned to 1:23. The actual output ('make') remained around 6,000 tons per annum until 1917, dropping to 4,000 after 1918, due to a reduction in the number of 'bargains' from 41 to 28. The 'make' continued to decrease to an average 2,500-3,000 tons per annum until 1937; thereafter, no independent figures for Quarry C are available[51].

In 1940, Quarry C still had an equal number of quarrymen to Quarry D (12 rockmen, 2 labourers and 2 day-men, compared to 11 rockmen, 4 labourers and 4 day-men, respectively) but after the suspension of Floor IX, c. December 1944, most of the men were transferred to Quarry D. A little work was done on the western side of Quarry C in 1945, but the area was unsafe, and had been abandoned by the summer of 1946; a bit 'fall' came down from that face on 12 December, 1947. Although there was a large body of rock available west of Quarry C, the quality was uncertain, and the land was overlaid by the old South Dorothea Quarry tips. Little work had been done on that side of the pit since 1887, when a section of land was transferred to the Dorothea Quarry from the South Dorothea Company (see Part IIIA; Figure 20). Experience gained from working that strip of rock had shown that the cleavage was warped, and the quality low. Thus, there was little justification in risking the limited capital available on clearing these tips and many thousands of tons of indifferent rock, in the hope of finding workable slate some distance into the face.

The only work done at Quarry C after 1946 was shaving the "red pillar" on the southern face of the pit. This was a body of good rock, some 150 yds. high x 20-30 yds. broad, but only about 10 yds. wide. It had been left in situ to support the quarry side, but this consideration was no longer important, as the lower workings had been abandoned. Two crews of rockmen (about 8 men), were employed to extract as much rock as possible, commencing near the top, and working progressively

downwards, in a series of steps. The manager, H.H.Jones, wanted to pursue this pillar southwards through to Quarry E, but permission was withheld because the main access route to the Office bank would be severed, and additionally there was little sign of workable rock on the northern face of Quarry E, where the blocks were of indifferent quality, and full of 'laces'.

After 1946, the bottom of Quarry C was used as tipping ground for the lower floors of Quarry D (Floors VI, VII). The old drainage adit on Floor VI provided access to the bottom of Quarry D in the 1960s, when a road was constructed to allow heavy plant to reach the working faces[52].

Winding Arrangements at Quarry C.

No details of the winding machinery are available pre-1860. In November 1860 a steam winding engine was purchased, and is shown on the oil-painting at Dorothea House (dated c.1861), working a two-carriage chain-incline. This was located on the eastern side of the pit, and the base (or 'galley') can still be seen. At the south-eastern corner of the pit (adjacent to Quarry B engine No.9) was an inclined plane which probably pre-dated the chain-incline. The former was probably worked as a water-balance, and would have ceased operating after the depth of the pit exceeded Floor II level, in the late 1860s. The site of this incline has been completely destroyed by quarrying[53].

In November 1869 a new 25 hp single-cylinder steam engine was bought (No.11, Figure 10) and erected on the southern side of the pit. This powered a four-carriage chain-incline, working at right-angles to the old plant. It is not known if both chain-inclines worked concurrently; despite the fact that the chains crossed each other, it was possible for both units to operate at the same time. The fate of the original Quarry C steam engine is unclear. By November 1884 it had been removed and possibly held in reserve. In 1885 the engine was installed on the new Incline A, as engine No. 3 (see above)[54].

The site of the old engine was chosen for a new 25 hp single-cylinder horizontal engine (No.10, Figure 10), working a two-carriage chain-incline erected on the southern face of the pit. The debris raised by this, and engine No.11, was raised to a second-level tip by transporter Incline C. This was constructed in 1883, and replaced a lower 'intermediate-level' tip. It is possible that the incline on first low tip was powered by a double-cylinder semi-portable engine (Official No.12), purchased in September 1878. This engine was used to wind the transporters on Incline C after 1883[55].

Two additional winding engines were installed at Quarry C in the early twentieth century, to serve the eastwards expansion of Floors VII and VIII post-1907. In that year, construction commenced on a large 'galley' on the site of Incline B (see Figures 10 and 10 overlay). The two independent chain-inclines (two-carriage)

on this 'galley' (termed Pyramid C) enabled debris to be raised directly to the second-level tip, whilst a simple hooking device allowed loads of blocks to be landed on the Office bank. The new engine room on Pyramid C (No.13a, Figure 10) contained two steam engines. One (Official No.13) formerly powered Incline B, and commenced working at the new site in 1914. The other (renumbered 13a) was formerly winding at Quarry A (Official No.1) and started working on Pyramid C in 1921[56].

Floor IX, opened in 1941, was provided with an independent winding system contrary to the normal working practice. This involved a two-stage lift, using two steam engines, and the deviation can be explained by the abnormal war-time conditions, when an emphasis was laid on maximum production. The lower half of the winding system consisted of a chain-incline (one-carriage) on a tip (Floor III) inside Quarry B (see Figure 11), raising blocks and debris from the Floor IX 'sink'. The winding wire for this apparatus extended down from engine No.4 on top of Pyramid B. The second stage was another single-carriage chain-incline, powered by engine No.3a, also on Pyramid B. The upper incline did not have a wooden landing-frame (or headstock), but used the structure of the Pyramid as a base for a simple 'catcher' mechanism, with the trolleys being landed on the Office bank only[57].

Pumping Arrangements at Quarry C.

Until 1906, Quarry C was drained via Quarry B, which housed the main pumps. Water from the former passed to the sump at the latter via an adit. Each new floor required a new adit, but the winding engine No.10, installed in 1884, was provided with an attachment for driving a pump via a long wire-rope. Thus, Floors VI and probably VII were drained by a pump lifting water to an adit on Floor V, saving the expense of driving a long adit to the centre of the quarry. It is possible that when the new Floor VII 'sink' was opened, Floor VI had been provided with a short adit through the partition to Quarry B. This would have maintained the pumping head at one floor, rather than doubling the height unnecessarily, and consequently reducing the fuel economy of the engine.

In the late 1890s, the quarry manager was advocating the reorganisation of the pumping system. The use of three pumping engines was uneconomical, and the cast-iron pump columns (or 'rising mains') were in an unsatisfactory location on the rock-face, being constantly broken by falls of rock. It was proposed that the pumping system be centralised in a single installation, housed in a special shaft, remote from the workings. This shaft would be connected to the deepest workings via an adit, and all the shallower pits would drain into the sump via connecting adits[58]. This plan was a copy of the installation at the Tal-y-sarn Quarry main pit, but was carried out at Dorothea on a grander scale. The main pumping shaft at Dorothea was 155 yds. deep; it was commenced in December 1899 and completed in 1903.

This shaft was 25 yds.deeper than the current bottom of Quarry C, and therefore a secondary shaft plus a 20 yd-long connecting adit were required. The project was severely delayed by rockfalls and the inrush of floodwater from the adjoining South Dorothea Quarry [59].

The original specifications envisaged the use of large horizontal steam engine working bucket-pumps, but the new quarry manager (post-1901) was greatly impressed by the reliability of the pumping machinery he had seen at the Cornish tin mines. A third option was electric pumps, but the Dorothea Quarry had, as yet, no power supply, and this plant was considered too new and unproven by the conservative Board of Directors (see Part IIIB). The Cornish Beam Engine provided the requirements of reliability plus sufficient power output, and thus a 68 in-piston diameter x 10 ft. stroke machine was purchased new from Messrs. Holman and Co.Ltd, Cambourne, Cornwall, in 1904. Second-hand boilers and Cornish force-pumps were bought, to reduce the cost, which had exceeded the original estimate of £5,000 by £7,750.

The new pumping set commenced work in 1906, and had a capacity of 1,055,125 gallons per 24 hours, which was about 70 per cent greater than the old pumps[60].

The Cornish Beam Engine (No. 20, Figure 10) worked until 1952, when in the interests of economy, electric pumps were installed. These consisted of two 60 hp 'Beresford' submersible pumps located in the sump. The

total capacity was 14,500 gallons per hour per pump, or 2,380,000 gallons per 24 hours. However, only one pump was normally used, with the second cutting in when required. The plant was automatic, being controlled by float-switches, with a master time-switch confining the operation to off-peak periods (see Part IIIA)[61].

The new Quarry C 'sink' Floor IX was excavated below the main sump, and was provided with its own bucket-pump. This was operated via a very long wire-rope from a two-cylinder steam engine located in an annexe to engine room No.19 (Figure 11), near the top of Incline A. The engine was allegedly obtained from a coal mine, in 1941, and was only in use for four years. The first part of the pump drive, along the quarry bank, consisted of wooden flat-rods, terminating in a pivoting quadrant, running on a curved length of rail. This transmitted the drive by ninety degrees, and the connection to the pump was made by a long wire-rope[62].

Quarry C Bank.

Quarry C originally shared the Office bank with Quarry B, but after the establishment of the second-level tip, separate slatemaking and tipping areas were established. The debris from Quarry C was initially concentrated to the west of the second-level tip, but by 1900 the tipping ground had been exhausted, and the material had to be transported eastwards as far as the mill tip. This ceased, c.1906, when second-level tipping recommenced, after about a decade of disuse.

From 1906-39 this tip increased greatly in area (see Figure 8), but to economise on fuel, the debris was diverted to the lower level (Office bank) c.1939-40. The site of the new tip was the abandoned southern half of Quarry E[63].

The Quarry C slatemakers were originally housed in huts ("waliau") on the Office bank (see Figure 8 overlay). The men were progressively transferred to the saw-mills as the number of Quarry B slatemakers diminished, in the late nineteenth and early twentieth centuries. After the closure of the latter in 1908, the mills were shared by Quarries C and D.

The buildings associated with Quarry C (Figure 10) were:

No 10. - engine room, built in 1884.
No 11. - engine room, built in 1869.
No 12. - engine room, Incline C winder, installed in 1883.
No 13a. - engine room, Pyramid C, erected in 1913.
No 18. - locomotive shed, 1870s.
No 20. - pump house (1904), containing a Cornish Beam Engine, which is preserved in situ.

Quarry D (Twll Bach).

At a shareholders' meeting of the Dorothea Slate Company on 11 November, 1861, it was resolved that a "new stage" be erected at the Cefn Tal-y-sarn Quarry, and on 5 September, 1862, H. and J. Ellis and Co. Manchester, were paid £260 for a new steam engine, which was installed at Quarry D[64]. Thus, Cefn Tal-y-sarn (the quarry behind Tal-y-sarn Farm) was the original name for the Small Pit (Twll Bach), officially designated Quarry D. The date of opening corresponds to the period immediately after John Hughes Williams, Caernarfon, became chief shareholder and chairman, and the commencement of a new pit on this site (Figure 5) was a logical progression in the development of the Dorothea Quarry. In the preceding 20 years it had been proven that two parallel slate veins traversed the property, on a south-west to north-east trend; also, the veins were bisected east-west near the centre of the liberty, by a large dolerite dyke, thus dividing the area into four quadrants. Quarries had been opened in three of these quadrants (A, B and C), and it was logical that the purple slate would be found in the last (north-western) sector. The reason why Quarry D was not opened earlier was purely financial. In the 1840s and early 1850s, Quarry C was being developed, and in the mid-late 1850s, the slate trade was experiencing a serious recession.

Little work was done at Quarry D during the nineteenth century (Figure 5). It had reached Floor III by the 1870s but in 1879 a landslide undermined the south-eastern corner, bringing down the chain-incline and the winding engine. Efforts were made to clear the debris via the drainage adit from Quarry B (using engine No.4 to lift the debris

up to Pyramid B), but this was given up for some unknown reason in April 1880[65].

Quarry D was the first Dorothea pit to have a significant amount of worthless overburden covering the slate vein. On the western and central portions, the overburden was composed of numerous alternating layers of sand and gravel, varying from 0-10 yds. thick. This material forms a band up to 20 yds. wide, which can be traced for several miles in both directions along a similar trend to slate veins, and the north-western side of Quarries C and E are also covered by this deposit. Numerous landslides occurred from the plot of land separating Quarries B and D, and also from the narrow (10 yds. wide) dyke separating C and D, the most notable being in 1891. Thus, in 1899, work commenced on cutting back this area of land. The overburden at this point comprised of grit-stone, which separated the purple and striped-blue slate veins. In this northern half of the property, the grit tapers gradually from a few inches width, at 100 yds. depth, to a few yards at some 40 yds. depth (similar to the southern sector), but then swells out in an immense belly of rock, overlying up to a quarter of the width of the purple slate vein (to the west). This 'cap' is about 60 yds. wide, 40 yds. deep, and extends north-eastwards for an unknown distance beyond the original Dorothea boundary. The whole structure is dipping north-eastwards, and was not discovered at the southern part of Dorothea (between Quarries B and C) because the upper portion had been removed by erosion.

The primary work carried out on the overburden was primarily for the benefit of Quarry B, and Quarry D could not be worked at this period because the access tunnel from Quarry B was still covered by a landslide. Also, the old access to the Quarry D chain-incline, across the grit partition between Quarries B and C, had been destroyed by rockfalls.

W.J.Griffiths, sub-manager from 1896-1899, soon realised after becoming quarry manager in 1900, that Dorothea had reached an important point in its development. Quarry A was on its last legs, Quarry B was rapidly deteriorating and had little working life remaining, Quarry C was in its prime, but would eventually start to deteriorate, and Quarry E was a failure. Thus, it was time to safeguard the future by developing new reserves, at Quarries D and F. Quarry D was reopened on 22 March,1902, the same date as the closure of Quarry A. Seven bargains were set, and the pit only made a gross loss of £520 in the first two years, whilst the debris was being cleared. From 1904-13, the pit averaged 1,500-1,600 tons ('make') annually, with about 20 per cent slatemaking yield and 1:15 overall quarrying ratio. The annual gross profit ranged from about £1,000 in the mid-1900s to about £2,500 in 1907-09, and reached £3,000-£4,000 by 1912-18.

The number of 'bargains' at Quarry Dincreased from 7 in 1902-11 to 10-13 in 1912-18, and reached 20 by 1921, by which time the 'make' averaged 2,400 tons per annum, with a gross profit of about £11,000. Although the output remained constant, the profits decreased after 1921 because of a reduction in the market value

of the slate. The slatemaking yield was high, at 25-30 per cent, but the ratio of blocks to rubble was lower here than in the remaining pits (C and E) during the 1920s because there was an increased pressure on output to make up the deficiency in the total Dorothea figure, caused by the landslides at Quarry C. The result of this unavoidable policy was to create a highly unsatisfactory state of affairs at Quarry D[66].

The pit was about 40 yds.deep in 1902 (Floor III), and a new 22 yd.-'sink' (Floor IV) was opened in July 1904. By 1913, there was sufficient space on Floor IV to allow a new 20 yd.-'sink' (Floor V) to be opened. At some date in the 1920s, another depth (Floor VI) was opened, all without any increase in the surface area (Figures 5 and 6). Some work had been done on clearing the top of the north-eastern face, but this had been largely suspended post-1926, due to the urgency of clearing debris at Quarry C. The ultimate result of such a policy would have been a disastrous landslide, but the manager was fully aware of the situation, and prepared plans to recommence developing Quarry D in 1934-5. The original scheme was disrupted by his death, in March 1935, and the new manager, Owen Giller (formerly sub-manager) formulated a new plan[67].

Owen Giller's development plan involved the total removal of the grit cap north-east of Quarry D. This was to be achieved by a system of galleries, similar to the Dinorwic and Penrhyn Quarries (Figure 12, overlay 2). Work on overburden clearance had to become a permanent feature of quarrying at Dorothea, rather than the old system of removing specific portions of rock in isolated projects, and using overtime

shifts during the summer months. The cost of this work was substantial; the gross profit of Quarry D was reduced from £5,097 in 1934 to £2,544 in 1935, and only £440 in 1936, when the overall quarrying ratio was 1:33.6. The yield in 1936 was good at 24 per cent, but the amount of blocks raised was down 1,000 tons on the previous year, due to the suspension of output for one month (February), whilst blasting was taking place in the overburden. Unfortunately, the output figures for Quarries C and D were combined after 1936, making analysis more difficult. However, the total output of the quarries increased after 1936, and the gross profit returned to the level of the early 1930s with the slatemaking yield at an exceptional 34 per cent. This shows that the scheme was successful, in that the expected deterioration did not occur. However, the less costly type of development work practised by W.J.Griffiths would probably have had exaactly the same effect on the figures, whilst also conserving the working capital[68].

The Second World War brought many problems to the Dorothea Quarry. From 1941-46, the slate industry was under the control of the Ministry of works, and pressure was exerted on the quarries to strive for maximum output. Whilst overburden clearance and development was probably not specifically banned, it was discouraged, and the reduced manpower available ensured that efforts were concentrated on production. In the traditional Nantlle style open pit (eg.,Quarry C), this was of little consequence, but Quarry D had been converted to the gallery-type system, and the effect of suspending the upper overburden galleries was catastrophic. Within a few years, the lower galleries had caught up with the upper ones, resulting in a reversion to a sheer-sided

quarry pit, with its attendant problems of instability and rockfalls. This situation was partially the fault of the quarry management, for a certain amount of overburden removal occurred from 1942-45 on the newly acquired ground west of Quarry D. Owen Giller was convinced that workable slate was to be found in the Tal-y-sarn Hall grounds (a view not shared by his predecessor), and when this property was purchased by the Company in 1942, he commenced to expand Quarry D westwards in preference to using the funds to maintain the gallery system on the productive eastern fact. O.Giller was so sure of the potential of the new ground that in 1945 preparations were made to tip the overburden into the bottom of Quarry D, which precipitated a dispute with the managing director. This led to Giller resigning, and a new manager, H H Jones, being appointed. Development work continued on a small scale at Tal-y-sarn Hall until the mid 1950s, but the quality of the slate rock was very indifferent, as had been predicted by the old quarrymen[69].

After the Second World War, the output of the Dorothea Quarry was on average 2,500-3,000 tons per annum, the larger part being produced at Quarry D. A major redevelopment scheme was commenced in 1946, to redress the effects of the war period, and from 1946-57, 23,000-56,000 tons of overburden was removed per annum, being most the grit body on the eastern side of Quarry D (Figure 12). In addition, the pit was deepened by one floor (to Floor VII) in 1947, so as to supplement the two remaining productive galleries, Floors II and VI. The physical form of the workings was highly unsatisfactory

in that there existed a sheer rock face, some 80 yds. high from Floor VII to II, in highly faulted slate rock. Efforts were made to restore the missing galleries, but only the upper portion had been completed by the mid 1950s, when a series of landslides devastated the pit; these occurred on 19 October, 1955, 22 February, 1956, and 1 February, 1958. On each occasion the narrow 'sink' (Floor VII) was filled with debris, and clearance operations were slowed down by the need to salvage workable slate blocks from the 'fall'.

Due to the aforementioned landslides, the scale of quarrying at Dorothea was reduced, with the workforce being decreased from 130 to 80 men in 1958. Consequently, the output declined to 1,000-2,000 tons per annum after 1958, and remained in this range thereafter. In the early 1960s the average quarrying ratio was 1:22, but overburden removal had ceased in April 1959. This was resumed in 1964, but no separate data is available; however, the total debris cleared increased from 22,187 tons in 1963 to 61,973 tons in 1964. A similar tonnage of debris was removed in 1965, but due to economic factors (explained in Part IIIC), this development work was largely curtailed in the mid to late 1960s[70].

Winding Arrangements at Quarry D.

A chain-incline was erected at Quarry D (Figure 12, overlay 1), and a steam winding engine purchased in November 1862. Both the engine and headstock were undermined by a landslide in 1879, but the pit was not very deep, and the former was salvaged, repaired, and set up at the new Large Mill in 1882, using a new boiler. The old boiler was stored, and used for winding engine No.1 Quarry A, after 1886. During the attempt at clearing the debris in Quarry D, via the drainage adit to Floor III, Quarry B, the rubble was raised to the surface using winding engine No.4.

Quarrying operations in the late nineteenth century had cut off the surface access to Quarry D, presenting problems for the future development of that pit (because there was no suitable site for a chain-incline to serve any gallery deeper than Floor III). However, the difficulty was overcome by erecting a Blondin Cableway (Figure 22), similar to that already used at the Pen-yr-orsedd and Ty'n-y-weirglodd Quarries. The cableway (No.D1) was erected in 1901, and was manufactured by J.M.Henderson and Co, Aberdeen; it cost £1,388 total, and had a span of 1,250 ft. The 50 ft-high main mast was sited on a tip formerly belonging to the Gallt-y-fedw Quarry, but transferred to Dorothea c.1900. The engine room (No.19, Figure 11) was built as close as possible to the mast, but nevertheless it was necessary to construct a substantial foundation platform on the slope of the tip. The winding arrangement was such that slate blocks were landed on the Quarry A bank (Office level), whilst debris was brought up to the Quarry A-B second-level tip (Figure 11).

The cableway initially performed disappointingly, because its maximum rate was 80 tons per day (about 60 loads), compared to double that amount from a single chain-incline. This was solely due to the fact that the former could only move one waggon at a time (compared with the one up-one down action of the latter), and the winding plus travelling distance was large. Therefore, the manager confined the action of the cableway to raising loads the short distance from Floor IV 'sink' (and later, Floor V) to Floor III, whence the waggons were pushed through the old adit, to Floor III, Quarry B. Then, the chain-incline (engine No.4) raised them for the larger distance, up to the surface. The logic of the system was that the cableway raising a short distance could equal the capacity of the chain-incline, winding over a long distance, and thus the overall amount of loads was increased[72].

This arrangement lasted into the mid 1920s, and up to 1935, a second chain-incline (engine No.3a), formerly listed with Quarry B was used to clear overburden in the area between Quarries A, B and D.

A change occurred in the winding arrangement after Owen Giller became manager in 1935. Engines 3a and 4 were stopped, and cableway D1 brought material over the whole distance to the surface. However, the total amount raised was reduced considerably by the deposition of much of the debris directly into the abandoned Quarries A and B. A second cableway (D2) was erected to the north of D1, using a new

mast and fittings, and a repaired steam winch, transferred from Quarry F (Pen-y-bryn engine No.4); this shared a boiler with engine No.19 (Cableway D1). A third cableway (D3) was erected in 1941, using masts moved from the old Quarry G bank. This used the old engine No.5, plus a loco-type boiler, obtained from an unknown source and was sited at Ffoundry Terrace (No.30, Figure 12). The tenants were evicted and the houses converted into engine rooms for Quarries D and G[73].

Pumping Arrangements at Quarry D.

Quarry D was drained via adits into Quarry B until 1906, and thereafter into Quarry C (Floors V to VII). Each new floor was provided with a new adit, and after 1935, these also served as means of transporting debris to the tipping ground at the abandoned Quarry B, for Floors III and IV Quarry D, and into the lower parts of Quarry C for Floors VI and VII (after 1945).

Quarry D Bank.

There has never been a separate bank for Quarry D. The material from the original chain-incline, 1862-79, crossed the isthmus between Quarries B and C, to be worked or tipped on the Quarry B bank. After 1902, the output of the pit was landed by the chain-incline No.4 (Quarry B) and cableways D1 and D2 on the old Quarry A and B bank, Office level, and the slate was worked in the two mills, shared with Quarry C. The debris was tipped on the eastern second-level tip, shared with Quarries A and B (see Figure 8).

Cableway D3 was erected on an area associated with Quarry G (see below).

Quarry E (Twll Newydd and Twll Cornwal).

Quarry E is an amalgamation of two formerly independent workings, the Dorothea Twll Newydd (New Pit) and the South Dorothea Quarry, colloquially known as Twll Cornwal. The Dorothea New Pit (designated 'E') was opened in February 1891, in consequence to the massive landslide which had drastically reduced production at Quarries A, B and C in January 1891. The site was south of Quarry C, on a strip of land between the main Dorothea workings and the outlet of the Lower Nantlle Lake (Figure 8). The Slight-Purple Vein was found immediately, but grit-stone was uncovered within a short space of time on the south-eastern side[74]. The slate was spoilt by cross-faulting, and the results were poor. Although Quarry E returned an annual gross profit of about £1,000 in 1895 and 1896, this had fallen to £539 in 1897 and £104 in 1898. The slatemaking yield was a reasonable 22 per cent, but the overall ratio was 1:39 because of the development work, entailing the removal of a large amount of overburden. Twelve quarrymen were employed at Quarry E in this period, and the pit was 30 yds. deep. Work was suspended in July 1899, but the planned sinking of an additional 20 yds. depth to test the deeper rocks was not carried out because the winding engine was urgently required for excavating the new Quarry C pump shaft[75].

After 1899, the neighbouring South Dorothea Slate Quarry Company Ltd. initiated a series of negotiations with the Dorothea Company, involving

an exchange of land (see Part IIIA(ii). Agreement was reached by 1903, and the deal included the transfer of ownership of part of Quarry E, which became absorbed into the workings of the South Dorothea Quarry (Figure 19). By the terms of the indenture, the latter was to work its main (northern) pit up to the common boundary by 1921, whereupon the face was to be handed over to the Dorothea Company to pursue the rock into the Dorothea land. The South Dorothea Company could have continued to work the southern part of the quarry after 1921, but in the event that Company went into voluntary liquidation, selling its assets and freehold to the Dorothea Company[76].

The Dorothea Company worked the South Dorothea Quarry (redesignated 'E') as an independent entity from 1921-37. Statistics are available for this period, and show a slatemaking yield of 24 per cent and an overall quarrying ratio of 1:16 for the first full year (1922). This ratio had deteriorated to about 1:20 by 1925 due to an increase in the amount of debris raised, and had reached 1:33 by 1934. The average gross profit in the 1920s was variable, decreasing from £7,000-9,000 in 1921-2, to £1,000-3,000 from 1923-32, whilst the 'make' remained within the range 1,000-2,000 tons per annum. After 1934, the profitability of Quarry E dropped dramatically, and work was suspended on 20 February, 1937, when only six 'bargains' remained, compared with a figure of 14 operating in the 1920s[77].

Four rockmen and four labourers were sent to reopen one face at Quarry E on 26 February 1938, with the produce being worked at the Dorothea mills. However, the men were withdrawn on 23 April 1938. Some work was done on that face in the 1940s, on a limited scale, but the last crew left in 1953[78].

Winding Arrangements at Quarry E.

The original Quarry E (1891-99) was served by a chain-incline (two-chain) on the Quarry C bank (No.14, Figure 10). This was powered by a semi-portable steam engine (No.14), formerly at Quarry A[79].

The South Dorothea main pit was worked by a transporter incline, which had been replaced by a chain-incline (two-chain) by 1921. The latter was replaced by a cableway (Cableway E, Figure 10) in 1933-34. The motive power was a double-cylinder steam engine of unknown vintage, inherited from the South Dorothea Company[80]. The South Dorothea small southern pit had two chain-inclines, but these were not used after 1914 because the quarried material was taken to the main winder, via a tunnel[81].

After the takeover in 1921, the Dorothea Company experienced difficulty in disposing of the Quarry E debris. This had formerly been tipped on a plot of land south of the river, but the high-level wooden bridge giving access to this tip had become unsafe. Thus, arrangements were made to raise debris up to the Quarry C second-level tip, via a new chain-incline (No.5, Figure 10). This was erected in 1923, and was powered by a Robey semi-portable steam engine (No.5), moved from

Pyramid B. Sufficient tipping space was available on the South Dorothea site for the mill (slatemaking) debris only up to the end of large-scale work, in 1937[82].

Pumping Arrangements at Quarry E.

From 1891-09, the winding engine (No.14) was used to operate a single lift of pumps at Quarry E[83]. After the transfer to the South Dorothea Company, the pit was drained by that quarry's pumps, operated by the transporter incline winding engine. This arrangement continued after the second transfer to ownership. In 1940, an electric pump was installed, to save the cost of running the steam engine whilst quarrying had ceased[84]. Pumping continued at Quarry E until 1969, long after the abandonment of that pit because of its close proximity to the main Dorothea workings.

Quarry E Bank.

The original Quarry E shared a common tip and slatemaking bank (Office level) with Quarry C. In 1921 the South Dorothea Quarry mills and bank came into the possession of the Dorothea Company, and these were utilised until 1937 (Figures 2 and 10).

The main building on the South Dorothea (or 'E') bank is the mill complex (No.40, Figures 10 and 15). This is a complicated construction, having been modified and extended at various periods. It is very ruinous and difficult to interpret. The oldest portion

was a seven-bay mill dating from c.1880. A row of slatemakers' cabins was added to the eastern side c.1890, plus a three-bay extension and a four-bay annexe. Between 1896 and 1900, an independent engine house was erected, the driving engine having been previously inside the mill. However, c.1900 the steam engine was replaced by a suction-gas engine, in a new room. The latter was replaced by a diesel-oil engine in 1934. In the inventory of plant and machinery of 1920, the mill contained 16 saw tables and 10 dressing machines. The plant was dismantled in 1940, and the building used for storage until c.1956, and it was demolished in 1965[85].

Other buildings on the E bank were:

No.41 - main pit winding engine, dating from the 1860s.
No.42 - sub-office, 1930s.
No.43 - smithy and carpenters' shop.
No.44 - two winders for the second pit, c.1900-10.

Quarry F (Twll Pen-y-bryn) and Pen-y-bryn New Quarry (Owen's Quarry).

The sites of these pits are identified on Figure 9. The Dorothea Company leased the Pen-y-bryn Slate Quarry after the failure of the Pen-y-bryn Slate Quarry Company, in 1892. Work commenced in August 1892 at a trial cutting, officially designated Pen-y-bryn New Quarry, but colloquially known as Owen's Quarry, named after the Dorothea manager, O.T.Owen. This pit was still under development

when J.J.Evans commenced his second term as manager, in January 1894. In a survey of the workings, dated 8 February, 1894, J.J.Evans commented unfavourably on the Pen-y-bryn New Quarry. He noted that the site was an area of great geological disruption. Grit had been uncovered ou the south-eastern side, and this extended at least 40 yds. south to the old abandoned Pen-y-bryn pit. This rock was also visible in a trial tunnel, underlying the striped-blue slate near the New Quarry. The full extent of the slate had been uncovered on three sides of the latter, showing that the deposit was only a pocket some 100 yds. wide. Although the slates were extremely durable, and red slate was known to underlie the lower grit, a large amount of expenditure was required to complete this development. In a three-month trial period, ending 24 March, 1894, the New Quarry produced only 39 tons of finished slate, at a loss of £151.4s.4d, and on 9 May, 1894, the Dorothea Board accepted the manager's recommendation that the development should cease[86].

The cessation of work at Pen-y-bryn contravened the leasehold terms, but the landlord was satisfied with assurances that quarrying would recommence as soon as the Nantlle Vale Drainage Scheme (draining the Lower Nantlle Lake) was completed. However, two years after this event, nothing had been done at Pen-y-bryn, and in May 1897 the Company was threatened by an order to surrender the lease. In response, work immediately started on developing a small pit, formerly known as Herbert's Quarry, named after William Herbert Jones, who

was a manager at Pen-y-bryn in the 1880s[87]. This was thereafter known as the Pen-y-bryn Quarry in the Dorothea MSS. After 1932, it was occasionally referred to as Quarry F, thereby completing an unbroken series of lettering by filling the gap between Quarry E and the newly-acquired Gallt-y-fedw Quarry, designated 'G'.

Quarry F was composed of two pits, relics of an ill-fated development by the defunct Pen-y-bryn Slate Quarry Company Ltd. In the 1880s that Company had spent a considerable sum on opening trial cuttings and adits, and this had influenced the Dorothea manager in his choice of a quarrying site in 1897. He considered this a better proposition than reopening the flooded Lower and Middle Quarries[88]. In a report dated 19 January, 1898, he outlined his development plan and quoted an estimate of £4,581[89]. However, this proved to be a vast underestimate, and his successor was called upon to explain the expenditure account of some £22,000 to the Board of Directors. In this report, dated 30 June, 1904, a detailed list of work carried out is given, and includes £2,500 for machinery, £12,750 on overburden removal and driving 643 yds. of tunnels and shafts. An annual output of 1,000-2,000 tons had been achieved in the years 1898-1903, but at an annual trading loss of £2,000-£3,000. This was due to the high development costs and a flaw in the rock, which caused a larger percentage of waste than normal. Nevertheless, it was expected that once the new Gallery III at the southern, and main, pit was opened, the quality of the rock would improve, and a profit made (Figure 4)[90].

The Dorothea manager had learnt from the bitter experience of his predecessors the perils of working the open-pit system of quarrying. Quarries A, B and C, had suffered disastrous landslides in the 1880s and 90s, due to faces being left unsupported over too great a depth, and a failure to cut back heavy overburden. Thus, Quarry F was developed on a modified system, where galleries were opened and continuously maintained within the open pit. Although the site was on a slope, it was not practicable to copy the open terraces at the Penrhyn Quarry, because of the immense cost of removing a large breast of grit-stone in front of the slate. Figure 4 illustrates this point, and shows that only the purple slate was easily available for quarrying. Unfortunately, the Red Vein was full of thread-like white 'laces' ("gwniadau"), whilst the Slight Purple Vein was disturbed by cross-faulting ("pefels"). Galleries I and II were inferior top-rock, but III and IV were expected to be clear of the faults[91].

Gallery III 'sink No 1' commenced working in January 1902, and to increase the rate of production, a second 'sink' was opened at the same depth, further east. The 61 yds. adit extension for the latter was started on 29 June, 1903, and the 19 yd. 'roofing shaft' up to Gallery II was completed on 23 March, 1904[92]. However, the quality of the rock, though improved, was still unsatisfactory, and the production costs remained high due to the necessity of maintaining overburden removal on Galleries I and II. Thus, Quarry F continued to yield a trading loss averaging £1,000 in the decade after 1903 (with the

exception of small profits made in 1906 and 1910)[93]. In response to the poor performance, the Board ordered the manager to suspend the overburden removal, and so reduce costs. The instruction was complied with under strong protest, and a dire prediction was given of the outcome of such a short-sighted policy[94].

The results of this decision were delayed by several years due to the suspension of work at Quarry F in August 1914. After the ending of the First World War, the slate industry experienced a boom, and consequently Quarry F was reopened, on 2 June, 1919. The Quarry returned a large profit of £3,493 in 1920, but on 19 February, 1921 some 96,000 tons of grit-stone collapsed into the lower workings, completely burying Galleries III and IV (the latter having been opened in 1912). The landslide was directly attributable to the suspension of work on Galleries I and II. Within a short space of time, the advancing lower workings, destroyed the latter, resulting in the formation of high faces of unsupported weak rock[95].

The cost of removing the debris led to a trading loss in 1921-22 of £4,793 and £3,316 respectively. Small losses were made in 1923-25, and small profits in the following three years. From 1928-32, the slate industry experienced a bad trade recession. This particularly affected Quarry F, where the flaws in the slate rock created both production and marketing problems. A loss of £1,598 was recorded in 1929, and a profit of £954 in 1930[96]. Short-time working was in operation at all the Dorothea pits through much of this period, but

on 18 April, 1931, Quarry F was closed down, so as to allow an increase in working days at the main Dorothea site. However, on 12 October, 1931, Quarry F was restarted, but only thick second quality slates were produced, to counter the abnormally high breakage rate sustained in transit by the thinner first quality slates (due to the geological defects). A trading profit of only £81 was made at Quarry F in 1931, and after an alternative source of slate had been obtained at the new Quarry G, F was closed indefinitely on 13 August, 1932[97].

The winding machinery and the sawing plant were removed by 1941, and the mill de-roofed. However, preliminary safety work was carried out at the pit in February 1942, but little work was done, and no details are recorded[98]. Quarrying restarted at F on 24 October, 1945, with five men extracting blocks on Gallery IV. The blocks were taken out via the lower drainage adit, at Nantlle Tramway level, and transported to the Dorothea Large Mill. On Monday night, 1-2 December 1947, a rockfall blocked the tunnel, at the quarry end. This was cleared, but the rock face continued to show signs of movement. On Friday, 29 September, 1950, a large crack was seen above the tunnel entrance, and the following day rockmen were sent to clear away the loose material. By Monday, 1 October, 1950, a marked movement of the face was observed, and the place was deemed unsafe to work. The 'fall' came down on 3 October, 1950, and the tunnel was blocked again. The amount of debris involved was too great to be worth the expense of clearing, considering the limited production, and consequently the pit was abandoned[99].

A geological survey of the properties owned by the Dorothea Company was carried out in 1963-64. This concluded that a substantial slate body lay north and west of Quarry F. The main Dorothea pits (D and G) were currently undergoing development, and a trial at Quarry F was considered a worthwhile investment, because an alternative supply of material would be invaluable as insurance against problems at the main site. A mechanical excavator cleared a large amount of top rock on the north-western side of Gallery I, tipping the debris into the abandoned pit. Although the slate rock was present, it was afflicted by the same faults as had ruined the quarry in the past. Thus, when the expenditure limit was reached, the new trial was abandoned[100].

Winding Arrangements at Quarry F.

The Pen-y-bryn New Quarry (Owen's Quarry) consisted of a large open cutting in an outcrop. At the eastern end is a flooded 'sink' of unknown depth, probably not exceeding 20 yds. A portable winding engine was used to raise material from the 'sink', and also to operate a pump, but no details of the machine are known. The slate blocks were brought down to the Pen-y-bryn Lower Mill via a long gravity-incline (Figure 9 overlay, and Figure 4).

The upper parts of Quarry F were worked via open cuttings. The top gallery of the upper pit was overburden exclusively, and had no communication with the remainder of the works. The next gallery down (No I), was the top gallery of the lower, and main, pit. This was at the same level as the second gallery of the upper pit, and they were

connected by a tunnel. Both pits have now been amalgamated. Slate blocks from this level were taken down a gravity-incline to the 'F Mill', which was at Gallery II level. The latter was also provided with a tunnel for both slate blocks, debris, and drainage.

The new Gallery III (lower pit), opened in 1902, was below the mill level. The gallery was created by extending an existing uncompleted tunnel, and it was originally intended that the slate should be taken out through this adit. The proposal included a new tramway connecting the adit with the Lower Mill (see Figure 9 overlay), but the plan was modified after the change of management in 1901[101]. The Gallery III tunnel was completed on 7 September, 1901, and opening out of the 'sink' commenced in February 1902. A cableway (F1) was erected to serve this 'sink', raising the material up to Gallery II, and the rock was then taken to the (upper) F Mill (Figure 9). A second 'sink' was opened on Gallery III level in 1903-04, and this was served by a second new cableway (F2). The cableways also served the new Gallery IV, opened in 1912. In later years quarrying destroyed Gallery II, and consequently both debris and blocks were landed by the cables on Gallery I, which was the main tipping bank. The blocks then had to use a gravity-incline to reach the mill[102].

After the closure of Quarry F in 1932, the plant was moth-balled for a period. In 1934, cableway F1 engine (officially numbered Pen-y-bryn No. 3) was dismantled, and parts sent for repair. It was

subsequently re-erected at Dorothea working the new cableway D2. Similarly, cableway F2 engine (Pen-y-bryn No. 4) was moved in 1940, to work cableway G (see below)[103]. When quarrying recommenced at F in 1945, the slate blocks were removed from the pit via the Gallery IV drainage adit. This was at Nantlle Tramway level, and was conveniently situated near the 3 ft. 6 ins. outlet tramway (see Figure 9). A petrol auto-tractor pulled the 2 ft.-gauge trolleys through the long tunnel, and these were then run straight onto 3 ft. 6 in.-gauge transporter waggons. A typical 'run' consisted of two transporters carrying two trolleys each, and this train would be hauled to the Dorothea main site by a horse. The trolleys were off-loaded at a platform near the foot of Incline A (Figure 11) and run on the 2 ft.-gauge lines to the Large Mill[104].

In 1963, a rough un-metalled road was constructed along an old cart-track to the F Mill bank, and a new extension made up to the site of the development on Gallery I.

Pumping Arrangements at Quarry F.

Each new gallery at Quarry F was opened by driving a tunnel into the hillside to a point underneath the existing workings. A 'roofing shaft' was then driven upwards to the daylight, and by this method, a new 'sink' was commenced. Water drained from the workings via these tunnels, and was discharged into the old flooded pits at the foot of the slope.

Pen-y-bryn New (Owen's) Quarry Bank.

The New Quarry bank consists of one small waste tip at the level of the new workings. A long gravity-incline led down from this to the old Pen-y-bryn Quarry bank (see Figure 9 overlay). The latter contained a mill, and the Dorothea Company had purchased most of the plant on that bank during the final dispersal sale of the assets of the Pen-y-bryn Slate Company in 1892[105].

The Lower Pen-y-bryn Mill contained six saw tables in four bays. There was only one room, shared by the slatemakers and the saws, ie there were no separate slatemakers' cabins. The mill line-shaft was driven by a very old vertical condensing rotary steam engine, which had formerly been a winding engine. Its remains were transferred to the North Wales Quarrying Museum, Llanberis, in January 1971 (No. 50, Figure 17 overlay, and Figure 17).

The tipping area of the Pen-y-bryn bank, and the gravity-incline leading to the Nantlle Tramway were south of the parish road. Communication between the two parts of the bank was via a bridge. This consisted of two spans, with a central 'island', some 40 ft. high. On this 'island' was a weighing-machine room.

Quarry F Bank.

Each gallery at Quarry F had an associated bank. Some were simple tips, and did not connect with other parts of the works; in this class were the Upper Pit upper bank, and the Lower Pit Gallery III bank. The main banks were at Gallery I and II levels.

Gallery I was the main tipping level for waste coming from the pit. It was also the site of the two cableways and slate blocks passed down a gravity-incline from Gallery I bank to the Pen-y-bryn Upper Mill (or F Mill) on the next level down. The F Mill (No. 51, Figure 9) was built by the Pen-y-bryn Slate Quarry Company Ltd, c.1884-85, and was contemporary with the Lower Mill. The general plan of the building (Figure 18) was similar to the latter, having one multi-purpose room. The F Mill was 12 bays long, and the southern (longitudinal) wall appears to have been added at a later date, probably after 1897. In the interim, the ends of the roof trusses were supported by vertical wooden beams (whose imprint remains on the later wall) with a wooden partition filling the gaps. It is assumed that the original intention was to add a second complete mill alongside the first portion, similar to the double-mills at the adjacent Pen-yr-orsedd Quarry. The Dorothea Company built a six-saw extension in 1902 with purple slate blocks, quite distinct from the blue material used in the first period. These purple blocks are found throughout the southern wall, and were built around the aforementioned vertical beams in the older portion only[107].

The F Mill plant had been removed after the dispersal sale of 1892, and had to be re-equipped by the Dorothea Company in 1897. Twelve saws were installed (six from the Lower Mill and the rest from stock), a single-cylinder horizontal steam engine was transferred from the old Pen-y-bryn Quarry, and a new Cornish boiler was supplied[108]. The mill was last used in 1932, and was moth-balled until c.1940, when the plant was scrapped and the building de-roofed.

Other buildings on the Gallery II bank (Figure 9) were:

No. 52 - two cableway engine rooms, built in 1902 and 1904 respectively

No. 53 - weighing machine room and smithy

No. 54 - weighing machine room and sub-office

A 252 yds. long gravity-incline leads down from the Gallery II bank, taking 3 ft. 6 in. gauge waggons from the stock-yard to the Nantlle Tramway, at Gallery IV level. At the foot of the incline there is a low loading platform, constructed in 1945, for loading 2 ft. gauge trolleys (leaving the Gallery IV tunnel) onto transporters en route for the Dorothea mills.

Quarry G (Twll Gallt-y-fedw).

The site of Quarry G can be seen on Figures 2 and 12. It was opened in the 1890s by the Gallt-y-fedw Slate Quarry Company Ltd, and was one of three pits worked at that quarry. In the 1900s, the proprietor was the Old Pen-y-bryn Slate Quarry Company Ltd, and 'Quarry G' was known as Twll Cae Ysgubor, named after the field in which it was opened. By the 1920s, this was the sole pit worked by that Company, and was generally known as Twll Gallt-y-fedw (Gallt-y-fedw Quarry). The Company went into liquidation in 1931, and the plant and machinery were purchased by the Dorothea Company. The latter purchased the Gallt-y-fedw freehold in 1932, and quarrying recommenced in March 1932, the pit being designated 'Quarry G'[109].

Prior to 1932 neither the Dorothea nor the Old Pen-y-bryn (Gallt-y-fedw) Companies had been able to work the large pillar of purple slate underlying the old parish road, which had been abandoned in 1927. Despite the closure of the latter, the Pant-du estate refused to alter the liberty boundaries. After purchasing the freehold of this estate, the Dorothea Company was able to exploit this slate rock, commencing with the southwards expansion of Quarry G[110]. A gross annual profit of £2,681 was made at that pit in 1932 and £4,213 in 1933. In common with other sub-units of the Dorothea concern, the financial returns for 1934-36 were greatly reduced, due to increased expenditure on development work. The amount of debris moved from Quarry G increased from 18,930 tons in 1933 to 35,359 tons in 1934, 29,268 tons in 1935, and 48,545 tons in 1936, whilst the 'make' remained steady at 1,400-1,800 tons. The pit returned a gross profit of only £1,945 in 1934 and £616 the following year, but by 1936 this had increased to £3,007. A normal quarrying situation had been reached by 1937, and analysis of the data shows a 24 per cent yield and an overall ratio of 1:26, with a gross profit of £3,584. Nineteen quarrymen were employed and 46 men on the quarry bank. Similar results were obtained in 1938, which was the last full year as an independent sub-unit[111].

A major reorganisation occurred at Quarry G after 1938. By that year the development of the workings southwards was arrested by the position of the cableway anchorages (Figure 12, overlay 2), and thus the winding

gear had to be re-located. Such a move would automatically isolate the G Mill (No.30, Figure 12) and create transport problems, but in addition, the manager planned to centralise all the sawing at the two Dorothea mills (see Part IIIB for details). Both problems were resolved by creating a new Quarry G bank and cableway, with a connecting tramway to the mills (see below). To enable these modifications to be carried out, quarrying was suspended at G in June 1939. Operations were greatly hampered by the outbreak of war, and Quarry G did not restart working until around January 1941. No separate summarised data is available for the individual pits after 1939, but the output from G must have been less than 1,000 tons 'make' per annum because only 8-10 rockmen were employed there[112].

The pit was closed in February 1947, and the five remaining rockmen were transferred to Quarry D. In the 1950s, the extraction of rock from the 'Gallt-y-fedw pillar' progressed from the Quarry D side, north-westwards (Figures 5 and 6), and all the upper portion had been removed by 1963, when large-scale development commenced at G. Heavy earth-moving plant was brought in, via the works road shown in Figure 12, and much of the debris which had been deposited in the Quarry G 'sink' in the 1930s, was removed. This allowed the Quarry D working face (from Floor III-VI) to advance northwards under the lower level of Quarry G (which was roughly the same depth as Floor III, Quarry D)[113].

Winding Arrangements at Quarry G.

Prior to the take-over by the Dorothea Company, Quarry G was worked by a single cableway (G1) of home-made design erected in the early 1900s (Figure 12, overlay 2). This incorporated the mechanical principles of a normal cableway, but modified to work partially by gravity, as a chain-incline. The single catenary cable was steeply inclined, due to the large difference in height between the tail-anchorage near the old parish road, and the main mast on the terraced quarry bank. A cableway-type load-carriage was used, and the winding and travelling cables were arranged in the normal manner. The innovation was in the control of the cables. Only the winding rope was attached to the engine, and the endless travelling rope passed around a braked sheave unit at the base of the main mast. Due to the incline, the load-carriage ran "out" over the pit under the control of gravity but could be arrested at any spot by the brake, thus conferring the advantage of a cableway to a chain-incline. This apparatus was constructed at the quarry smithy, and enabled an existing winding engine to be used without modification, consequently saving on expenditure. The engine was an old De Winton single-cylinder horizontal moved from one of the old Gallt-y-fedw Quarry pits (disused) and set up adjacent to the G Mill (No. 31, Figure 12) so as to share the mill engine boiler. This meant that a very long winding rope was required because the site was remote from the cableway[114].

In 1933, the Dorothea Company wished to increase the hauling capacity at Quarry G, and tenders were invited for a conventional cableway. However, the unit erected (G2) in that year was of similar design to the existing cableway. This used a chain-incline winding engine (double-cylinder horizontal) probably purchased from the defunct Tal-y-sarn Quarry (Figure 12, overlay 2)[115].

The whole layout of Quarry G was altered in 1939-40. A conventional cableway (Cableway G3, Figure 12) was erected east-west across the pit, with the engine installed in the old shop at Foundry Terrace, Tal-y-sarn Uchaf. This engine was a two-cylinder steam winch transferred from Quarry F. It was powered by a small loco-type boiler (previously supplying the pump; see below), but in 1946 the disused G Mill large horizontal boiler was transferred to Foundry Terrace, to supply both the Cableways G and D3 engines[116].

Pumping Arrangements at Quarry G.

Quarry G was pumped by a small Worthington Duplex steam-powered pump situated in the sump. The original vertical boiler was also at the pit bottom, but the replacement loco-type boiler had to be placed on the ground surface because of its size. An electrically-powered pump was installed in 1940, worked by the Company's private generator. After the Quarry D workings had broken through the rock partition into Quarry G, pumping was unnecessary as the water then flowed into the

Dorothea Quarry sump. The Quarry G pump outflow discharged northwards into an old tunnel, formerly the route of the Nantlle Tramway (Figure 12, overlay 1)[117]. The tunnel can be inspected for the first 200 yds, but the western end is closed by a collapse or by tipping from the Tal-y-sarn Quarry. Water still flows along it from a drainage adit leading from an old quarry, and the stream surfaces over half a mile to the south-west of Dorothea, near the Coedmadog Quarry. Thus, the water discharged from Quarry G somehow found its way through to the Tal-y-sarn Quarry drainage system, but no details of the exact physical connection nor the legal position are known (Figure 19).

Quarry G Bank.

The Quarry G bank consists of a number of terraces, each representing a different phase in the history of the Gallt-y-fedw Quarry (see Figure 12 overlays). The top terrace was constructed in the 1890s and the new gravity-incline was completed in 1897. The Ordnance 1899 survey shows the main portion of the G Mill (No.30, Figure 12). This was composed of six bays with individual slatemaking cabins, as at the Dorothea Small Mill, but both gables were of slate-rubble construction, such that no extension was apparently planned. However, by 1916, a row of slatemakers' huts ("waliau") had been built outside the mill, and about a dozen extra sawtables placed outside, in a similar manner to the Dorothea Large Mill (see above). In contrast, these saws were never roofed-over at Quarry G.

The G Mill site expanded rapidly from 1899 to 1916, with the addition of many ancillary buildings (Figure 16). On the same level as the mill proper were a smithy and fitting shop, and carpenters' shop. On the next level were the mill engine-room (with a single cylinder horizontal steam engine), air-compressor, mess-room, boiler house and coalyard, and on the old upper bank were the old cableway engine room and a second, aborted engine room (dating from the 1920s).

Other buildings on the mill bank (Figure 12) were

No.32 - office

No.33 - mess-room (caban) and weighing machine

No.34 - cableway engine room, 1933.

Dorothea Quarry Water Supply.

A generalised plan of the water supply is shown on Figure 19. Pre-1932 there were two sources of water which were combined at the Pen-y-bryn Quarry, and then passed on to the Dorothea Quarry (see Part IIIA for details of the water-rights). The two sources were the Cilgwyn Quarry drainage adit, and an aqueduct abstracting from two streams half a mile east of the Dorothea Quarry. This aqueduct passed through the Pen-yr-orsedd Quarry, working one water-wheel, before joining the Cilgwyn supply on the hillside above the two Pen-y-bryn Quarry water-wheels. The tail-race then ran in an open ditch to Pen-y-bryn hill, crossing the road on a high wooden launder.

Once outside the Dorothea Quarry, the water was originally passed over three water-wheels, but this number had decreased to two by 1894, and only one remained after c.1900. The first in the series was the Upper Water-wheel, pumping Quarry A (see above). It was erected in the 1830s, rebuilt in the mid-1850s, and had become disused by 1894. The second, or Middle Water-wheel, powered the slab mill c.1840-c.1900, and the third, or Lower Water-wheel, pumped Quarry B (see above). This wheel had been on at least two different sites, and ceased operating in 1906.

During the development of the quarry, the actual course of the internal water system was modified several times, especially when the water-wheels were moved or discontinued. This was also the case with the water-mains supplying the steam boilers. The general plan of the system is known in part, but much cannot be traced. Major modifications were carried out to the main supply in the 1930s. Firstly, a pipe-line was laid from the Gwernoer Quarry (Figures 2 and 19) to supply the Dorothea Cornish pumping engine, a distance of some half-a-mile. By that date, the Pen-yr-orsedd portion of the main water-supply had been lost, leaving only the Cilgwyn source. Fortunately, the reduced volume of water was sufficient to meet the requirements of the Dorothea Quarry in the 1930s. The number of steam boilers in use at the works had been reduced from about 20 in 1900 to about nine in 1938, and the water-wheels had been dispensed with in the early 1900s.

After a number of years, the Gwernoer water-supply had to be discontinued, because the highly-mineralised water caused a deposition of crystals within the boilers of the Cornish pumping engine. Consequently, a higher input of water was required from the Cilgwyn source, to make good the loss of the Gwernoer supply. A system of ditches was excavated on the Cilgwyn hillside, collecting all the available surface water into an old pit, Owen's Quarry (see Quarry F above). The water flowing from the Cilgwyn Quarry adit was also re-routed to the new reservoir. A new 2 ins. diameter pipe-line was laid to bring the water direct to the Dorothea Quarry bank. This proved adequate for the needs of the works for the remainder of its operating life[118].

PART II NOTES

1. W. G. Fearnsides and T. O. Morris, 'The Stratigraphy and Structure of the Cambrian Slate-belt of Nantlle (Caernarvonshire)', Quarterly Journal of the Geological Society, vol. lxxxvii, pt.2, 250-303

2. ibid., Plate XVIII, increased in scale.

3. Dorothea MS 1261.

4. In the possession of Mr. M. J. B. Wynne Williams, Dorothea House, Tal-y-sarn.

5. The Dorothea MSS contain a photographic record of the workings in the 1930s and 1960s, and further evidence was obtained from the author's private photographic collection.

6. Dorothea MS 1261.

7. J. Griffiths, Chwarelau Dyffryn Nantlle a Chymdogaeth Moeltryfan (Conway, 1934), p.35.

8. loc.cit.

9. J. Griffiths, op.cit., pp.35-39.

10. Dorothea MS 1.

11. ibid., MSS 612, 614.

12. 'Ab Owain', 'Hunangofiant Chwarelwr', an unpublished essay entered for the Dorothea Quarry Eisteddfod held at the Assembly Rooms, Tal-y-sarn, 8 May 1926.

13. ibid., Dorothea MS 1138.

14. ibid., MS 1140.

15. ibid., MS 1195.

16. ibid., MS 560-1.

17. ibid., MSS 1, 5, 561.

18. ibid., MS 563; ex.info.Mr. O. Humphries.

19. J. Griffiths, op.cit., p.36; R. Williams, 'Hunangofiant Chwarelwr', Cymru, 1900.

20. See note 4 above.

21. Dorothea MS 1.

22. ibid., MSS 612, 614.

23. ibid.

24. ex.info.Mr. G. Roberts.

25. J. Griffiths, op.cit., p.35.

26. The exact date is not known.

27. Dorothea MS 1.

28. Dorothea MSS 1178, 1254.

29. ibid., MSS 911, 1178.

30. J. Griffiths, op.cit., pp.39-42.

31. Dorothea MSS 5, 560-1.

32. loc.cit.

33. ibid., MS 5.

34. ibid., MSS 1, 612, 614; Dorothea oil-painting, 1861 (see Note 4 above).

35. Dorothea MSS 612, 614; Gwynedd Archives Service, G. P. Jones Collection (unclassified), Dorothea sub-manager's notebook, 1890s.

36. Dorothea MSS 612, 614.

37. loc.cit., MS 1266; ex.info.Mr. G. Roberts.

38. G. P. Jones, coll., University of Hull Practical Industrial Archeology Course, August 1979, investigation of the Dorothea Lower Water-Wheel, Pumps, and Adits, by S. A. Holm, Dr. G. A. Rawlins and T. R. Smith; Dorothea MS 1266.

39. J. Griffiths, op.cit., pp.40-1; Dorothea oil-painting, 1861, op.cit.

40. loc.cit., Caernarvon and Denbigh Herald, 1873, reports of a special correspondent on the North Wales slate industry; Dorothea MSS 614, 1145; Ordnance 25" 1 mile, sheet XXI 9, 1888.

41. Dorothea MSS 5, 612, 614.

42. ibid., MSS 612, 614; ex.info.Mr. G. Roberts.

43. ibid.

44. Dorothea MSS 612, 614.

45. G. P. Jones, coll., Machinery Purchase Ledger, 1930s (unclassified); ex info., Mr. G. Roberts and Mr. L. Jones.

46. J. Griffiths, op.cit., pp.44-5; Dorothea MS 911.

47. ibid., MS 1.

48. loc.cit.

49. Dorothea MS 5.

50. The average ratio of 'make' to excavated material in open slate quarries is usually quoted as 1:20.

51. Dorothea MSS 560-3.

52. ibid., MSS 668, 1216, 2119; ex.info. Mr. M. J. B. Wynne Williams.

53. Dorothea oil-painting, op.cit., Dorothea MS 612.

54. ibid., MSS 612, 614, 1250.

55. ibid., MSS 612, 614.

56. ibid.

57. ex.info. Mr. G. Roberts and Mr. L. Jones.

58. Dorothea MS 1254.

59. ibid., MS 612.

60. ibid.

61. ibid., MSS 829, 830.

62. ex.info. Mr. G. Roberts and Mr. L. Jones.

63. Ordnance maps, sheet XXI 9, 1888, 1889 and 1913 surveys.

64. Dorothea MS 1.

65. ibid., MS 615.

66. ibid., MSS 561-3.

67. ibid., MS 5; O. Humphries, 'Datblygiad Chwarelyddiaeth Dyffryn Nantlle y Chwarter Canrif Diwethaf' (unpublished essay, December 1943).

68. Dorothea MS 613.

69. O. Humphries, op.cit; ex.info. Mr. M. J. B. Wynne Williams.

70. Dorothea MSS 1422, 2119.

71. ibid., MSS 612, 614, 615.

72. ibid., MS 880, letters dated 10 November, 1902, and 17 February, 1903.

73. ibid., MS 1216, ex.info., Mr. G. Roberts and Mr. L. Jones.

74. Dorothea MSS 5, 615.

75. ibid., MSS 561, 615.

76. O. Humphries, op.cit; ex.info. Mr. G. Roberts.

77. Dorothea MS 563.

78. loc.cit.; G. P. Jones coll. Notebook of Dorothea Quarrying Statistics, 1950s (unclassified).

79. Dorothea MSS 612, 614.

80. ex.info. Mr. I Hughes; G. P. Jones coll., Ledger of machinery purchases and repairs. The first reference to "Cableway E" occurs in 1934.

81. ex.info. Mr. I Hughes.

82. Dorothea MSS 614, 1484.

83. ibid., MS 615.

4. ibid., MS 1451.

5. Ordnance maps; ex.info. Mr. G. Roberts; examination of remains by the author.

86. Dorothea MSS 2, 5, 1254.

87. ibid., MSS 2, 44; G. P. Jones coll., Plan of Pen-y-bryn Quarry, c.1884 (unclassified).

88. Dorothea MS 1945, pp. 629-640.

89. ibid., MS 1254.

90. ibid., MSS 5, 983, 1254.

91. ibid.

92. ibid., MS 614.

93. ibid., MS 44.

94. ibid., MS 880, letters dated 4 August, 1904, 16 February, 1906, and 14 February, 1907.

95. ibid., MSS 44, 885, p.895.

96. ibid., MS 44.

97. ibid., MSS 4, 44, 1004.

98. ibid., MS 668.

99. ibid., MS 669.

100. ex.info. Mr. M. J. B. Wynne Williams.

101. Dorothea MS 880, letter dated 31 January, 1900.

102. ibid., MSS 612, 614.

103. ibid.

104. ex.info., Mr. L. Jones.

105. Dorothea MS 614.

106. ibid., MS 612.

107. ibid., MS 983; G. P. Jones coll., Pen-y-bryn Plan.

108. ibid., Machinery repairs ledger (unclassified); Dorothea MSS 612, 983.

109. ibid., MSS 20, 1346-7; O. Humphries, 'Datblygiad Chwarelyddiaeth' op.cit.

110. ibid.

111. Dorothea MS 563.

112. ibid., MSS 1216, 2119.

113. ibid., MS 2119; ex info. Mr. M. J. B. Wynne Williams.

114. ex info., Mr. G. Roberts.

115. ibid.; Dorothea MS 1285.

116. ibid., MS 612; ex.info. Mr. G. Roberts.

117. ibid.

118. ibid.