Information Sheet 1G: General tectonic evolution and structural geology

General tectonic evolution of the area

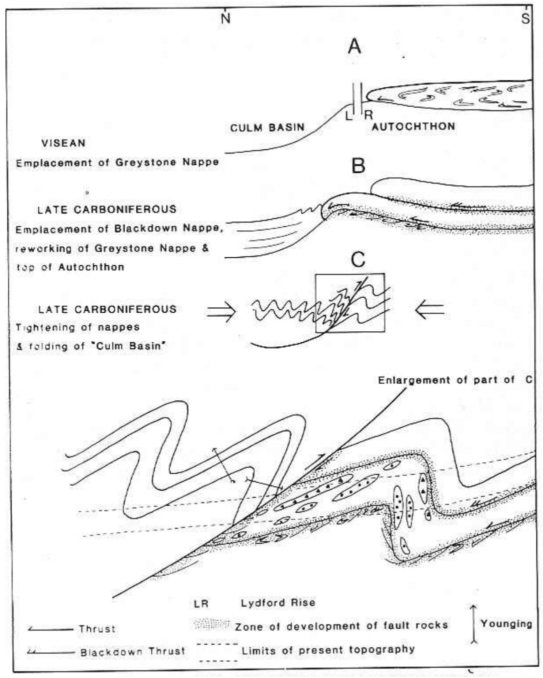
The late Lower Carboniferous in the region is marked by the beginning of the tectonic activity which climaxed with intrusion of the Dartmoor granite close to the Carboniferous-Permian boundary. This activity, the Variscan Orogeny, was a direct consequence of the tectonic plate collision of Africa with Europe. As Sediments which had accumulated in ocean basins between the continents were squeezed up and thrust over each other as nappes, to form a vast mountain chain, running from eastern North America (which was joined to Europe at the time), through Cornwall and Devon to Belgium, the Czech Republic and beyond (Issac et al 1982; Issac 1985; Woodcock and Strachan 2000). This event had a very fundamental effect on the Devonian and Carboniferous rocks of south-west England and is reponsible for most of the folding and faulting seen in the older rocks of the counties.

The first major tectonic event to affect the area was the arrival from the south of the Lower Culm Group of the Greystone Nappe in the latest Lower Carboniferous following gravity sliding from a submarine rise an unspecified distance to the south (Sellwood and Thomas 1984). Friction and shearing during emplacement created a thick slaty, mylonitic unit formerly misidentified as a stratigraphical unit – the *MeldonSlate-with-lenticles 'Formation*' (see Sheet 1C).

Flysh sedimentation developed in the latest Lower Carboniferous and Upper Carboniferous with turbidites derived from the rising Variscan mountains to the south, flowing northwards into the Culm Basin of central Devon and North Cornwall to form the distal deposits of the Crackington Formation. Much closer to the source of this sediment, the Bealsmill Formation was being deposited, eventually to also be dislocated within the Blackdown Nappe, and then slid northwards on top of the Greystone Nappe, to arrive in the area in the late Carboniferous. Meanwhile further compression began to affect the Culm Basin autochthon, developing steep parallel east-west alligned folds in the Crackington Formation and eventually some overthrusting across the Greystone and Blackdown Nappes, as described by Sellwood and Thomas (1982) near Belstone to the east.

When the Dartmoor granite arrived at the end of the Carboniferous, it appears to have had further tectonic effects, as the Greystone and Blackdown nappes of the Meldon district are folded in a broadly anticlinal structure which bends around parallel to the edge of the granite, and does not have the normal region east-west trend. Such a structure suggests that the folding developed to accomodate the granite mass as it was emplaced – probably as a series of intruded sheets (see Sheet 1E; G. Taylor, Univeristy of Plymouth, in discussion 11/05). This late phase of deformation would be that noted by Sellwood and Thomas (1984) which folded the Greystone and Blackdown nappes together to form the so-called '*Meldon anticline'* – actually a folded double-nappe complex.

A characteristic feature of such deformation in other areas such as Chile (cf. Grocott and Taylor 1992), is the development of mineralisation at the focus of the accommodation-folding where deformation is concentrated immediately in front of the emplaced granite mass – could this be an explanation for the belt of skarn-type mineralisation of the Meldon-Sticklepath district?



A schematic structural history of Belstone (to Meldon) district (after Sellwood & Thomas 1984). Used with the author's permission.
A: Emplacement of the Greystone Nappe from the south by gravity sliding in the late Lower Carboniferous (Late Viséan), possibly from an area separated from the Culm Basin of mid Devon by a submarine rise (the 'Lydford Rise').
B: Late Carboniferous arrival of the Blackdown Nappe which reworks the Greystone Nappe and the top of the autochthon of the Culm Basin (i.e. the Crackington Formation), causing some backthrusting of the latter.
C: Late Carboniferous folding of the Culm Basin and the combined Greystone-Blackdown Nappe sequence (the latter possibly, in part at least, related to accommodation of the granite intrusion, as discussed below).

The area also includes some evidence of much later tectonic activity, most importantly the Pewsley Fault, a distinctive NW-SE structure along which the West Okement River has cut its very distinctivecut 3km+, straight valley. This allignment parallels the well-known Sticklepath Fault to the east and although it is likely to be originally a Variscan structure, reactivation during the 'Tertiary' is likely (possibly during the Neogene Period, linked to Alpine tectonic activity in southern Europe).

Key features and exposures of structural geological significance in the Meldon area

LOCALITY	NGR	DESCRIPTION	REFERENCES
LC2: West Okement river (below viaduct)	5643924 to 56429245 (LC2a); N of 56449240 (LC2b); 56519225 (LC2d); 56499277-56429245	River bed exposures with key structural features within the Greystone Nappe include: LC2a - Including mylonitic horizon (= *'Meldon Slate-with-lenticles'*) (hard, finely banded brown, greenish grey and purple hornfels with seems of silty quartzite) exposed for over '450 yd', bounded by faults. LC2b - Massive tuff and agglomerate below viaduct, with shaly hornfels with thin quartzitic bands above and below (i.e. upstream	Dearman (1959), Edmonds *et al.* (1968, pp.25, 30, 41, 168, 181) (see also Sheet 1C)

	(LC2e).	and downstream) faulted against mylonitc unit at 56449240 (Meldon shale and Quartzite Formation). LC2 - NE of Meldon Pool (=LC7), shows inverted chert and calc-silicate hornfels on the east side of the river (Firebeacon Chert Formation) dipping steeply NNW and N. LC2d - Cherty hornfels and shale also exposed near the old limekiln (central syncline) (Firebeacon Chert Formation) L2e - Normal limb of the northern anticline, showing grey and white banded chert dipping 30o-40o NNW, apparently with junction with overlying Crackington Formation (?faulted); to the S. faulted against mylonitic unit. Anticline and syncline at 56439257 and 56439257 respectively (Firebeacon Chert Formation).	
LC3: Meldon Quarry	56909270 (LC3a); 56949206-57159220 (LC3b); 56919208-57009221 (LC3d); 56769242-57039252 (LC3e); 56899274-57169295 (LC3g); 57009220-57159220 (LC3I); 56809240-56989246 (LC3j); 56989295-56979298 (LC3k).	Large and geologically famous active aggregates quarry showing excellent exposures through metamorphosed Lower Culm Group of the Greystone Nappe. Structural geological features are of national importance (hence designation as Meldon Quarry SSSI) (see Parkhouse 2003 for a full description of exposures in the current working quarry). General location of key structural features within the Greystone Nappe as recorded by Edmonds *et al.* (1968) include: LC3a - Fault bounded exposures of mylonitic unit (='Meldon Slate-with-lenticles') reported in 'Middle Bay' (1968) – including isoclinally folded purplish brown slaty and banded hornfels with small lenses and laminae of quartzitic siltstone. LC3b - Area showed both inverted and normal limbs of the southern anticline with shaly hornfels with minor silty quartzite in the Meldon Shale and Quartzite Formation dipping 60o-80o NNW (1968). LC3d - Normal limb of southern anticline included (in 1968) hornfels in the Meldon Shale and Quartzite Formation with tuffs faulted against Firebeacon Chert Formation to the NE. Meldon Shale and Quartzite Formation also seen in northern anticline with volcanic units (tuff dominated) developed within shaly-hornfels with thin beds of silty quartzite (seen in normal and inverted limbs with dips often around 40o-70o NW/NNW). LC3e ('Gullet Back') - Included (in 1968) the inverted limb of northern anticline, and showed a similar sequence in the t Meldon Shale and Quartzite Formation to LC3d (1968). LC3g area - Flat-lying isoclinal folds recorded in grey hornfels overlying tuff and hornfels (Meldon Shale and Quartzite Formation) with thin Firebeacon Chert Formation above (1968). LC3i - Greyish-green, black and white banded cherty and calc-silicate hornfels (Firebeacon Chert Formation; northern limb of southern anticline; dip 30o S) (1968). LC3j - Greyish brown and reddish brown weathered silts and cherts with minor folding and faulting (Firebeacon Chert	Beer and Fenning (1976), Dearman (1959), Dearman and Butcher (1959), Edmonds *et al.* (1968, pp.25, 27, 30, 33-37, 42, 89-91, 129, 132, 168, 169, 175, 176, 181, 207; pls 3a and 5A, 10A); Parkhouse (2003), Scrivener (2003), Howie (1965), Worth (1920), etc. (see also Sheet 1C).

		Formation); dips 55o-80o NW-NNW (inverted limb of northern anticline) (1968).	
LC4: Red-a-Ven Brook / Meldon Aplite Quarries SSSI (part)	56849201-56929182 (LC4a); 56719202 (LC4b); 56979173 (LC4c).	Stream bed and quarry exposures of the Lower Culm Group, (Lower Carboniferous) in the Greystone Nappe). Inverted limb of southern anticline well exposed in the brook (characteristic dips 50o-70o to the NW or NNW), with the normal limb downstream, near the Aplite quarries (with characteristic dips 25o-40o to the NW or NNW). Includes volcanic units of the Meldon Shale and Quartzite Formation, overlain and underlain by metamorphosed shales and quartzites. Exposures with key structural features within the Greystone Nappe include: LC4a area - Includes grey shaly hornfels with minor silty quartzite in the river bed and adjacent crags above the eastern bank. Structurally overlain upstream by '190 ft' of tuffs and acclomerate. and then '75 ft' of further grey shaly hornfels with occasional thin quartzite bands (56939185-56959182) (Meldon Shale and Quartzite Formation). LC4b - Interbedded tuff and hornfels of normal limb of southern anticline present in stream between and above Aplite quarries, faulted against hornfels of inverted limb (Meldon Shale and Quartzite Formation).	Dearman (1959, p.95), Dear and Butcher (1982), Edmonds *et al.* (1968, pp.26, 33, 34, 40) (see also Sheet 1C).
LC12: West Okement River (above confluence with Red-a-ven Brook)	56429181 (LC12a); 56429185 (LC12b); 56419199 (LC12d)	Exposures in bed and banks of river show partial sequence through the Lower Culm Group (Lower Carboniferous) sequence of the Greystone Nappe – majority of former section now flooded beneath Meldon Reservoir (= LC12c). Exposures with key structural features within the Greystone Nappe include: LC12a - Meldon Shale and Quartzite Formation recorded in river, including hornfelsed shale with thin quarzite bands, typically with dips NW–NNW at around 70o (inverted limb of southern anticline). Volcanic units formerly exposed upstream but now submerged by reservoir. LC12b - Exposes the northern limb of the southern anticline including shaly hornfels of the Meldon Shale and Quartzite Formation dipping NW below the Firebeacon Chert Formation. LC12d - Firebeacon Chert Formation in the normal southern limb of the central syncline includes chert and cherty hornfels dipping at 25o-45o. At the confluence with Red-a-ven Brook, green calc-silicate hornfels dip at 80o S, with cherty hornfels downstream dipping at 30o-35o NW.	Edmonds *et al.* (1968, pp.32, 33) (see also Sheet 1C)
Q9: West Okement river west of Homerton Hill	559901	Valley cut along the line of the Pewsey Fault, a Variscan NNW-SSE structure, probably reactivated during thre Neogene.	Edmonds *et al.* (1968, p.198) (see also Sheet 1x).

Key references

BRITISH GEOLOGICAL SURVEY 1994. Tavistock, Sheet 337 (Solid and Drift Edition). *England and Wales, 1:50,000 Provisional Series,* NERC.

BRITISH GEOLOGICAL SURVEY 1995. Dartmoor Forest, Sheet 338 (Solid and Drift Edition). *England and Wales, 1:50,000 Provisional Series,* NERC.

CLEAL, C.J. and THOMAS, B.A. 1996. Culm Trough, In: CLEAL, C.J. and THOMAS, B.A., British Upper Carboniferous stratigraphy. *Geological Conservation Review Series* **11**, Chapman and Hall, London, pp.37-55.

DEARMAN, W.R. 1959. The structure of the Culm Measures at Meldon, near Okehampton, North Devon. *Quarterly Journal of the Geological Society, London* **115**: 65-106.

DEARMAN, W.R. 1962. Dartmoor, the North-west margin and other selected areas. *Geologist's Association Guides* No.**33.** Benham and Company, Colchester, 29pp.

DEARMAN, W.R. 1964. The tectonics of the Upper Culm Measures around Okehampton. *Transactions of the Devonshire Association* **96**: 208-227.

DEARMAN, W.R. and BUTCHER, N.E. 1959. The geology of the Devonian and Carboniferous rocks of the North-west border of the Dartmoor granite, Devonshire. *Proceeding's of the Geologist's Association* **10**: 51-92.

DEARMAN, W.R and EL SHARKAWI, M.A.H. 1965b. The shape of the mineral deposists in the Lower Culm Measures of north-west Dartmoor. *Transactions of the Royal Geological Society of Cornwall* **19:** 286-296.

DURRANCE, E.M. and LAMING, D.J.C. 1982. *The Geology of Devon*, University of Exeter, 346pp.

EDMONDS, E.A., McKEOWN, M.C. and WILLIAMS, M. 1975. *South-west England* (4th Edition). British Regional Geology, Institute of Geological Sciences, 136pp.

EDMONDS, E.A., WRIGHT, J.E., BEER, K.E., HAWKES, J.R., WILLIAMS, M., FRESHNEY, E.C. and FENNING, P.J. 1968. Geology of the Country around Okehampton. *Memoir of the Geological Survey of Great Britain (England and Wales)*, HMSO, 256pp.

GROCOTT, J. and TAYLOR, G.K. 2002. Magmatic arc fault systems, deformation partitioning and emplacement of granitic complexes in the Coastal Cordillera, north Chilean Andes (25o30'S to 27o00'S). *Journal of the Geological Society of London* **159**: 425-442.

INSTITUTE OF GEOLOGICAL SCIENCES 1969. Okehampton: Sheet 324 (Solid and Drift Edition), One-Inch Series, Institute of Geological Sciences.

ISSAC, K.P. 1985. Thrust and nappe tectonics of west Devon. *Proceeding's of the Geologist's Association* **96**: 109-127.

ISSAC, K.P., CHANDLER, P., WHITELEY, M.J. and TURNER, P.J., 1983. An excursion guide to the geology of central south-west England: report on the field meeting to West Devon and East Cornwall, 28-31 may, 1982. *Proceeding's of the Geologist's Association* **94**: 357-376.

ISSAC, K.P., TURNER, P.J. and STEWART, I.J. 1982. The evolution of the Hercynides in central S.W. England. *Journal of the Geological Society of London* **139**: 521-531.

PARKHOUSE, S. 2003. Meldon Quarry, Okehampton – Geodiversity Audit Report. David Roche Geoconsulting Report No. 2237/11VE. In: *Geodiversity Audit of Active Aggregates Quarries: Quarries in Devon*. Mineral Industry Research Organisation, Devon County Council, David Roche Geoconsulting, British Geological Survey, Devon Stone Federation, Mineral Industry Sustainable Technology Programme (available on CD).

ORMEROD, G.W. 1867. Notes on the Carboniferous beds adjoining the northern edge of Dartmoor. *Transactions of the Devonshire Association* **2**: 124-128.

PAGE, K.N. 1999a. Meldon Aplite quarries. In: DRANDAKI, I., FERMELI, G. and KOUTSOUVELI, A.., *GRECEL (Geolgical Heritage: Research in Environmental education and Cooperation in European Level): Educational Pack (Second Edition)*, Athens

PAGE, K.N. 1999b. Geoconservation in Devon - The developing infrastructure. *Geoscience in south-west England* **9**: 352-357.

PAGE, K.N. 2006. *Parish Geodiveristy Audit: Okehampton Hamlets*. Devon Aggregates and Biodiversity Project: Report for Aggregates Industries and Devon County Council.

SELWOOD, E.B. and THOMAS, J.M. 1884. A reinterpretation of the Meldon Anticline in the Belstone area. *Proceedings of the Ussher Society* **6**: 75-81.

SELWOOD, E.B. and THOMAS, J.M. 1987. Dinantian sedimentation in southwest England. In: MILLER, J., ADAMS, A.E. and WRIGHT, V.P., European Dinantian Environments, *Geological Journal Special Issue* **12**: 189-198.

SCRIVENER, R.C. 2003. Appendix A: British Geological Survey Report - Meldon Quarry, In: PARKHOUSE, S., Meldon Quarry, Okehampton – Geodiversity Audit Report. David Roche Geoconsulting Report No. 2237/11VE. In: *Geodiversity Audit of Active Aggregates Quarries: Quarries in Devon*. Mineral Industry Research Organisation, Devon County Council, David Roche Geoconsulting, British Geological Survey, Devon Stone Federation, Mineral Industry Sustainable Technology Programme (available on CD).

THOMAS, J.M. 1988. Basin history of the Culm Trough in southwest England. In: BESLY, B.M. and KELLING, G. (eds), *Sedimentation in a synorogenic basin complex: the Upper Carboniferous of Northwest Europe*, Blackie, London

TURNER, P.J., 1982. The anatomy of a Thrust: The Greystone Thrust Complex, Esat Cornwall. *Proceedings of the Ussher Society* **5**: 270-278.

WHITELEY, M.J. 2004. Culm Trough, In: COSSEY, P.J., ADAMS, A.E., PURNELL, M.A., WHITELEY, M.J., WHYTE, M.A. and WRIGHT, V.P., British Lower Carboniferous stratigraphy. *Geological Conservation Review Series* **29**, Joint Nature Conservation Committee, Peterborough, pp.477-503.

WOODCOCK, N. and STRACHAN, R. 2000. *Geological history of Britain and Ireland*. Blackwell, 423pp.

WORTH, R.H. 1920. The geology of the Meldon valleys near Okehampton on the northern verge of Dartmoor. *Quarterly Journal of the Geological Society, London* **75**: 77-118.

Author: K.N. Page 2006