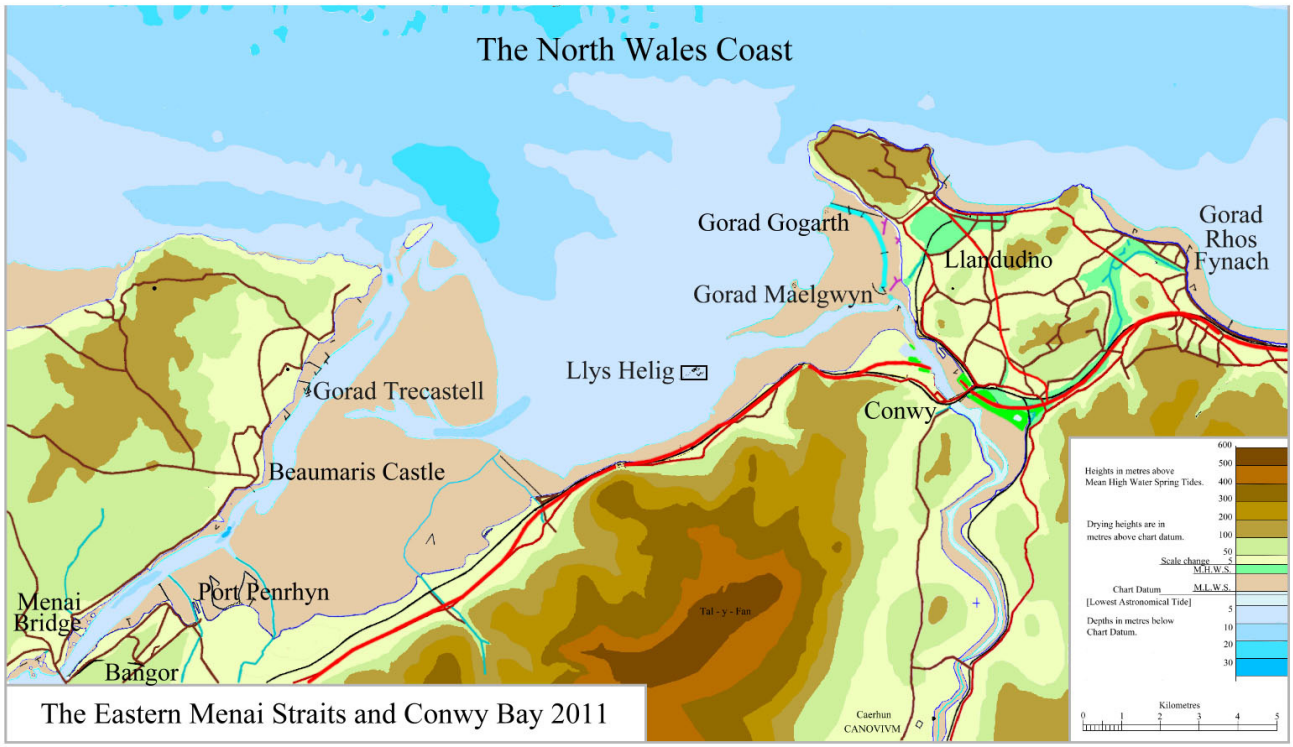
Flood, Folklore and Fishweirs

Interpreting localised relative sea level changes
by means of geomorphological, historical and
archaeological analysis of intertidal structures.



The Eastern Menai Straits and Conwy Bay 2011

N.V. Campbell Bannerman.

2011

Flood, Folklore and Fish Weirs

An analysis method for assessing and interpreting localised relative sea level changes involving the geomorphological, historical and archaeological analysis of intertidal structures.

Abstract

Data on relative sea level fluctuations focused on the Menai Straits and Conwy Bay were collected over a fifteen year period and combined with observations on Holocene geomorphology, archaeology and marine environmental history. These observations and correlations have allowed the changes in sea level in relation to the vertical positions of features and structures in the inter-tidal zone to be measured. This has permitted a graph to be plotted of Relative Sea Level changes measured against geological and marine historical structures and related to Ordnance Datum.

Inundation legends and folklore tales of lost lands have a central role in the maritime cultural heritage of Wales. These may spring from oral traditions of actual storm related events and may also be attempts to explain the numerous submerged forest beds of the area. Conwy Bay for example possesses a persistent tradition of a submerged palace, known as Llys Helig, supposedly lost in a 6th century storm.

The observations reported here are drawn from the wider context of marine environmental history research into coastal change in the Menai Straits the Anglesey coast and Conwy Bay. They are limited to studies of the evidence for relative sea level changes. Associated factors such as erosional and accretional processes are not examined in this paper.

The method of analysis works best in areas which have a large tidal range. Places with such conditions have long utilised the rise and fall of tides to capture fish in specialised fish weirs. This is one of the most ancient marine technologies. In Wales such fish weirs are known as ‘Goradau’* and form important historical assets in the areas where they survive. The North Wales Coast offers many sites for study allowing inter-site correlation of features which might otherwise be dismissed as aberrations.

To be most effective the lowest part of a fish weirs where the fish are collected and known as the ‘sluice’, should be slightly above the level of Mean Low Water Neap Tides. In the study area old fish weirs sluices are found extending below what is now the level of Lowest Astronomical Tide. In Conwy Bay, which has a reasonably large tidal range this is at least 2.9m lower than the optimum level and suggests a relative sea level rise of that amount since the trap was constructed.

Modifications to fish weir structures in response to relative sea level rises provide datum points for measuring relative sea level fluctuations. Furthermore datable wood excavated from secure contexts within fish weir foundations the can help to ascertain dates for these indicated fluctuations.

A unique feature of the research is the use of ancient fish weirs as datum points - a method proposed in an earlier paper [Bannerman, 2000]. Natural and man made structures within the Intertidal zone such as reef features, the quays of the castles constructed by Edward 1, and more recent harbour walls, have also been examined and researched for evidence.

This research was carried out in association with Dr. C. Jones, The Cemlyn Jones Research Fellow, School of Ocean Sciences, Bangor University

*singular ‘Gorad’

The Development of Study Methods

The investigations are based on field work complemented by the study of old charts and documents on coastal history.

The transfer of data from old charts and maps onto modern surveys has been one of the main approaches in the reconstruction of recent coastlines. These studies sought to determine whether coastline change was occasioned by erosion, accretion or relative sea level change, acting alone or in combination. Only the relative sea level category is examined in this paper. Admiralty Hydrographic Charts can also be used to establish baseline depth contours from which paeleocoastlines can be inferred. [Bell, M. 2007] But when the measured effects of erosion and accretion are included a more accurate assessment can be made. Aerial photographs were specially taken on very low tides identifying reef features and fish weirs, parts of which were below the level of Lowest Astronomical Tide [L.A.T.]. By 2000 observations were published [Bannerman, N.V.C. 2000.] that disagreed with the then accepted Relative Sea Level [R.S.L.] curve for the area [Heyworth & Kidson 1989] but are in line with other more recent research. [Roberts, M.J. 2006.]

Investigations were pursued into a sequence of substantial modifications to the fish weirs known as Gorad Trecastell located at Aberlleiniog in the north east Menai Strait. These modifications, which had twice involved rebuilding the foundation structure and moving it landwards higher up the beach were in response to a total R.S.L. rise of more than 1.8m.

Many weirs such as Gorad Trecastell can be found in this area. These often have a total length of more than 300 metres and run out at carefully designed angles from the shoreline. One is documented as being at least 1500 years old having been gifted to St.Cybi's monastic college Holyhead by the Welsh King Maelgwyn Gwynedd d. 547, others are documented as being in use in the Middle Ages [Carr. A.].

They work by trapping fish on the falling tide behind stone and wattle fences, in almost all cases extending down the beach from High Water Mark. The fish are then concentrated at the lowest part in a 'V' shaped 'sluice' which needs to be just above Low Water Neap Tides allowing the catch to be collected on more than 95% of low tides. This location is also vital for repair and maintenance such as clearing accumulations of sea weed that could over burden the wattle fences causing them to collapse under the pressure of waves or currents. This critical level can be easily established by simple observation over a number of tidal/lunar cycles. Reports of single tide catches of several thousand fish are found in the records, an interesting comparison with the productivity of modern day fisheries which highlights their socioeconomic food source importance. In the first 5 years of this research sufficient data were accumulated to allow a tentative classification of fish trap types found in North West Wales. [Bannerman & Jones 1999]

Percentages of useable tides quoted in illustrations and text include tides occurring during hours of darkness when catch collection would be very difficult.

Individual fish weirs are often known by several names while some discovered in this study have none recorded. Wherever possible the most well known Welsh name is used or an appropriate name allotted. Thus 'Gorad Trecastell' is used instead of 'Gorad Mawr' or 'The Big Weir' and 'Gorad Collins', after Hydrographer Capt.Grenville Collins, instead of 'Ware' or 'Fish Weir'.

It is held that fish weirs and other features within the intertidal zone can provide useful and accurate measurements which, when combined with geological and archaeological observations, produce important insights into the pattern of Relative Sea Level change in a given locality.

The sites studied including national grid references are:

[The point where a fish weirs abuts, or abutted, the shore are given as its position]

Gorad Gwyrfai, near Caernarfon Western Menai Straits SH 4525 6105

Gorad Trecastell on the Anglesey shore of the Eastern Menai Straits. [Main Site] SH 6190 7875

Gorad Gogarth, on the southern shore of the Great Orme. SH 7610 8250

Gorad Maelgwyn, on the shore between Llandudno and Deganwy. SH 7710 8050

Gorad Rhos Fynach, Rhos on Sea SH 8430 8085

Llys Helig Reef, in Conwy Bay [central point of site] SH 7220 7870

Beaumaris Castle SH 6075 7630

Port Penrhyn [data collection point] SH 59150 72800

Geologically the sites studied are underlain with Till deposited at the end of the last Ice Age and since eroded to different degrees. While this enables like for like comparisons to be made it has been necessary to observe caution as at Aberlleiniog. Here the beach substrate consists of areas of Late Devensian sands and gravels and Holocene deposits [Helm,D.G. Roberts,B. 1984.]. The presence of alluvial coal in the Devensian sand and gravel facies at Aberlleiniog [Wood, M.1994] could affect radiocarbon dating of sediments from this area. The problem of coal fragment contamination of sediments has been discussed in another paper [Roberts, M.J. 2006. p239] but special reference was not made to this site.

Measurement of Sea Level Fluctuation at Key sites

Fish Traps as R.S.L. Datum Points by Measurement

After an initial survey with an optical level showed interesting results a fully professional survey was commissioned to establish levels at Gorad Trecastell which shows two levels of modification after construction.

The 3rd phase of Gorad Trecastell is shown on the 1840 1”/mile Ordnance Survey maps, the two lower phases are not. Neither are the adjacent two Aberlleiniog fish traps, the sluices of which are at the same level as Gorad Trecastell Phase 2 and as such most probably abandoned as being inefficient. This would appear to indicate that in 1840 only Gorad Trecastell Phase 3 was in use. The long and high fences of post and wattle would be both a prominent landmark and a danger to navigation. Hence with Aberlleiniog tidal range a fish trap sluice needs to be 0.15m above Mean Low Water Neap Tides [M.L.W.N.] to be useable on 95% of tides and Gorad Trecastell Phase 3 sluice is now 0.8m below that optimum point it would appear that in 1840 M.L.W.N. was 0.95m below present levels.

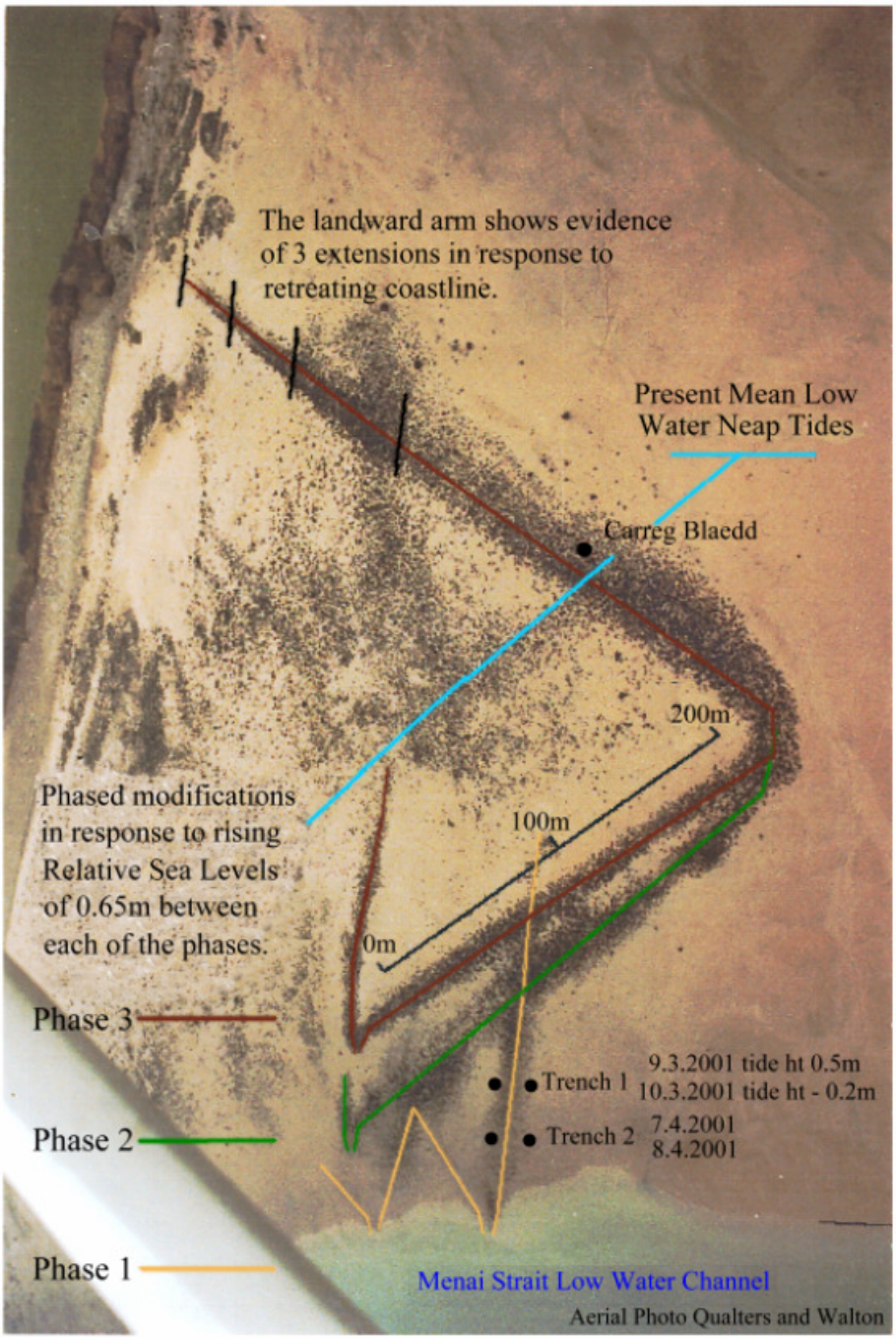
The Phase 2 sluice is at the level of Mean Low Water Spring Tides [M.L.W.S.] which is 1.65m below optimum level and at the present time would only be useable on 14% of tides.

The Phase 1 sluices are at least 0.15m below Lowest Astronomical Tide [O.D.–4m] or 2.9m below optimum level and as such unusable on any tide at the present time. This strongly suggests that there has been an R.S.L. rise of at least 2.9m since Phase 3 was first built.

Aberlleiniog

Gorad Trecastell

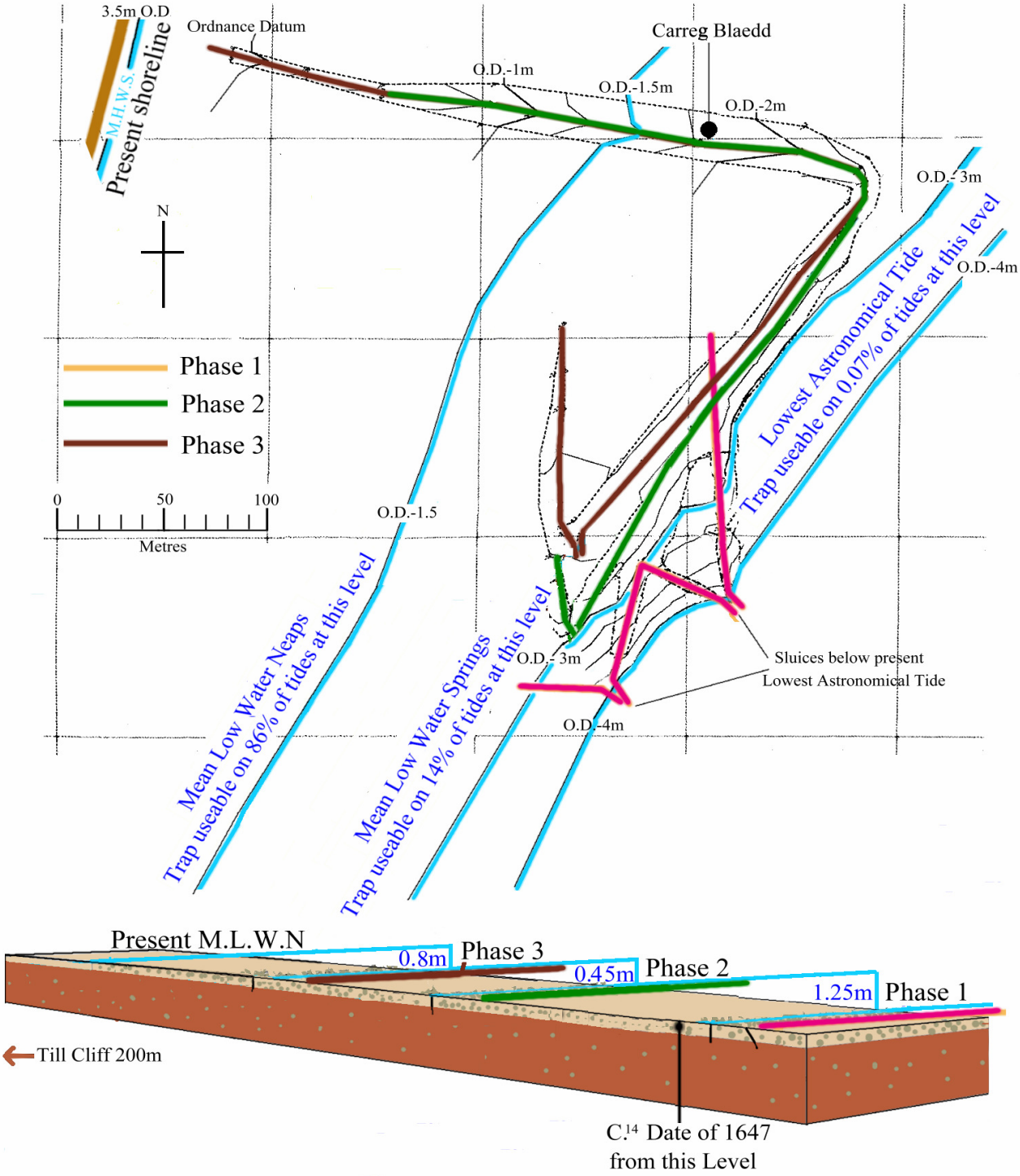
Low Water 9.3.1997 17:48 hrs GMT Height of tide -0.1m. Lowest usable tide 1997



At the present time the highest phase would only be useable on 14% of tides. To be of use today another modification would have to be built just above the level of Low Water Neap Tides. This indicates a total Relative Sea Level rise of 1.95 metres since Phase 1 was built.

Aberlleiniog

Gorad Trecastell 2010



At the present time Phase 3 would only be useable on 42.5% of tides. If a Phase 4 were to be built it would need to be above the level of Mean Low Water Neaps by 0.15m. At that level it would be operational on at least 95% of tides. This strongly suggests that Relative Sea Level has risen 2.65m. since Phase 1 was built.

Fish Traps as R.S.L. Time Frame Datum Points by Carbon 14 [C.^{14}] Dating

C.^{14} results have given indication of dates for the measurable vertical levels of fish weirs within and below the intertidal zone. Samples of wood for C.^{14} assay were taken from fish weirs with sluices, or the point where fish were trapped, below present Mean Low Water Spring Tides [M.L.W.S.] and as such usable on only 14% of tides. This in Conwy Bay suggests a 1.7m to 2.85m lower R.S.L. at the time the weirs were in use. The dates are:

Gorad Trecastell 1670. Aberlleiniog Anglesey [1st phase] Sluice below Lowest Astronomical Tide

Gorad Gogarth 1500. Southern shore of the Great Orme. Sluice not visible but close to Lowest Astronomical Tide

Gorad Gwyrfai 1600.Western Menai Straits between Caernarfon and Fort Belan. [Although this fish trap is outside the immediate study area it is an important comparative site.]

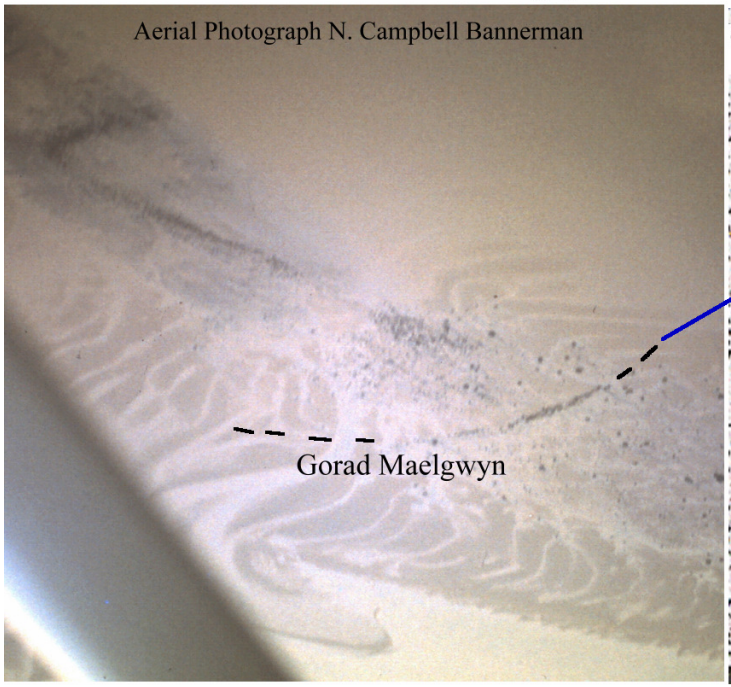
Fish Traps as R.S.L. & Time Frame Datum from Admiralty Charts

The Sluice of Gorad Rhos Fynach at Rhos on Sea is shown on the 1835 Admiralty Chart as being at the present M.L.W.S. which is now 1.5m below present optimum level [Robinson,C.1835]. This fish trap was abandoned shortly after 1910, a contributory factor was its inefficiency.

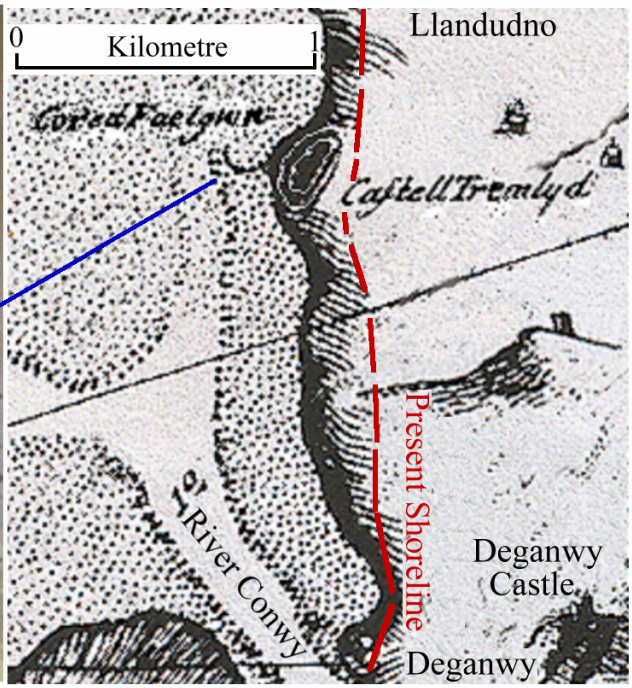
Fish traps and Archive Derived Datum Inferences

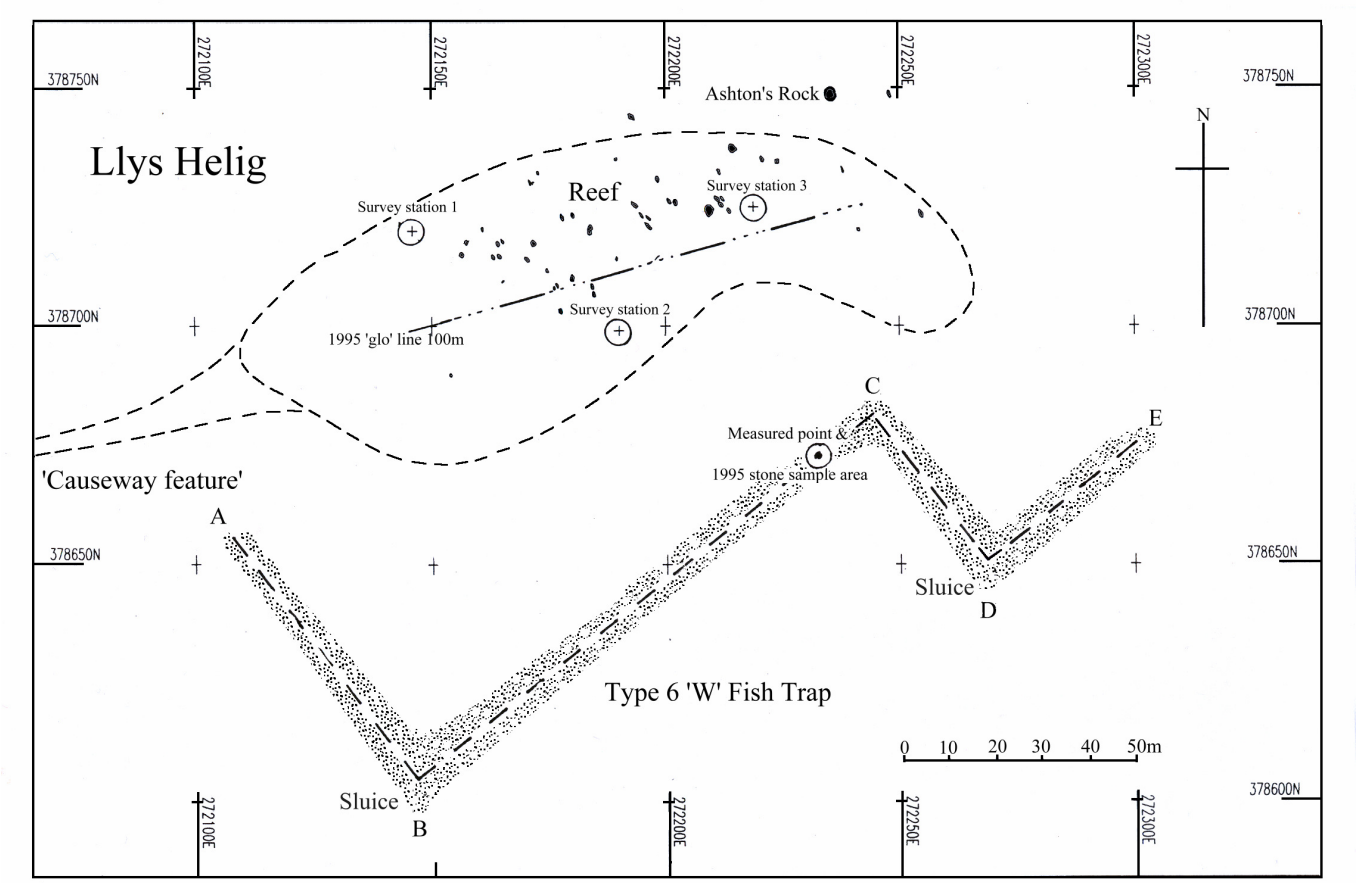
Where archival references infer a fish weir was in regular profitable use it is fair to conclude that the weir was at a level close to the optimum at that time. For this reason Gorad Maelgwyn near Deganwy could be used as evidence that around 1300 R.S.L. was close to present level as it is now also close to optimum level. Evidence for its productivity comes from the records that circa1300 local villeins paid the considerable sum of 40 shillings/per annum rent for Gorad Maelgwyn '*in addition to their own rents services and customs*' [Davies, H.R.1942]. In this particular case extra caution should be exercised as Gorad Maelgwyn may have originally been more of an estuarine fish trap which due to coastal erosion has now become a marine trap and as such subject to different tidal characteristics.

1996. Erosion reveals Gorad Maelgwyn



Detail from a 1748 Lewis Morris Chart





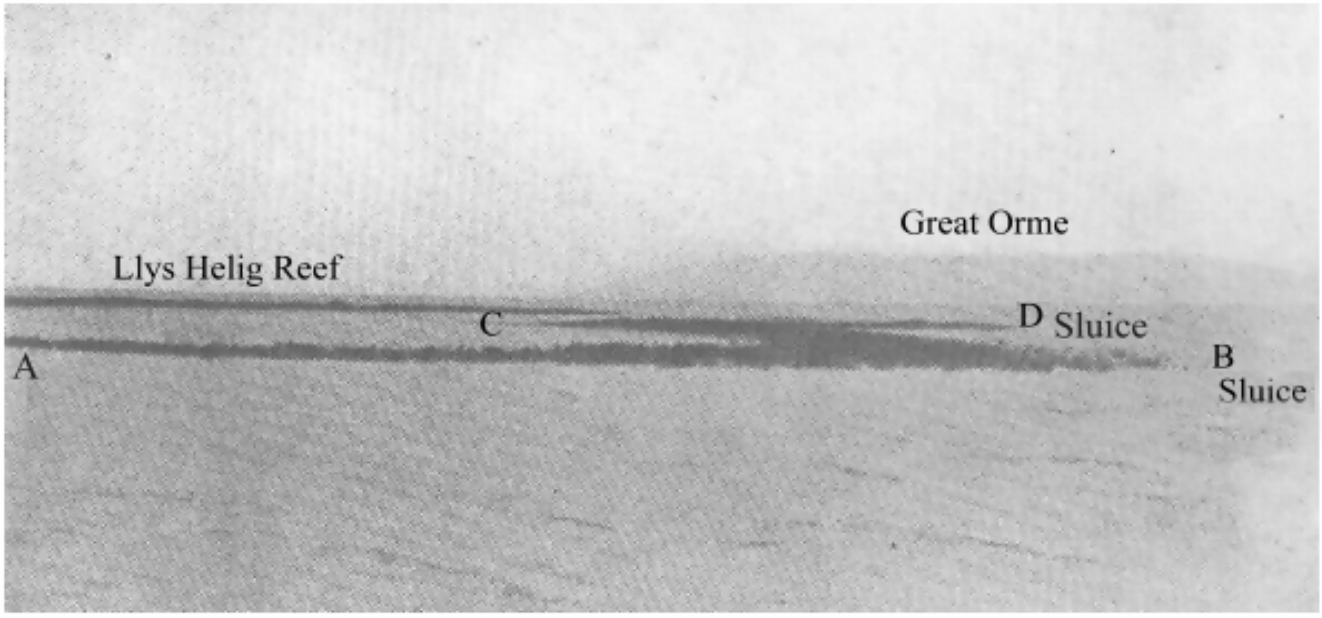
Llys Helig Reef as an R.S.L. & Time Frame Datum for Conwy Bay

Although at first this site was considered to be only a natural feature initial appraisal indicated the possible presence of a fish weir. With professional assistance a survey combined with details from specially taken aerial photographs, located and confirmed features described in 1864 and 1913.

Llys Helig is a natural reef in Conwy Bay thought to be the remains of an eroded Drumlin possibly underlain by solid rock [Wood,D.]. To the south of the main reef is a large 'zig zag' feature most probably a Type 6 'W' Fish Weir very similar to Phase 1 of Gorad Trecastell with sluice level about 0.5m lower. Tradition dates this to 500 A.D. but the indicated lower R.S.L. circa 1600 suggests it could have been usable at that time giving substance to the legends surrounding the site as described by Sir John Wynne of Gwydir 1554-1626 [Wynne 1906]. The possibility that this feature was a fish weir was also mentioned by visitors to the site on the 19.8.1864 [Parry, R. 1864] & [Hall, C.1864]. Their reports and plan make it obvious that the feature was visible. In the 19th and early 20th centuries visitors were able to make plans [Arrowsmith, J. 1907] and take photographs of a structure on the reef the tops of the boulders of which now rarely break surface. Some of these photographs, taken at 0700hrs 13.9.1913, show a drying height of 0.5m [Ashton,W.1920]. The predicted height of tide on that date would today completely cover the site to a depth of 0.6m. Hence the photographs indicate an apparent rise in R.S.L. of 1.1m. A visit to Llys Helig Reef requires settled conditions with a calm sea and no wind which would discount the possibility of storm surges being responsible for such a low level. See Unusual Events – Tidal Surges.

Photographs taken At Llys Helig Reef by H.Lee's party 3.9.1913 at 0700hrs.
Predicted Low Water 0650hrs. height 3.6m below Ordnance Datum.

Note that the furthest boat is drawn up onto the fish trap arm which has dried by circa 0.5m



A - B - C - D relate to points on survey.

Llys Helig reef is shown on charts from 1735 onwards. The 1835 Admiralty Chart [Robinson.C.1835] shows the reef drying. Modern Admiralty Charts show the reef with its 0.7m boulders as covered to a depth of 0.3m [Admiralty Chart SC1463]. Essentially rising R.S.L. has been recognised by showing the reef now covered at low water but the surrounding depths are still those taken in 1890 or earlier. The continued presence of features photographed and

described in 1913 precludes the possibility that the reef is being drastically eroded. During the study period the reef has never been seen to dry even on Lowest Astronomical Tides suggesting that in 1835 M.L.W.S. in the order of 1m lower.

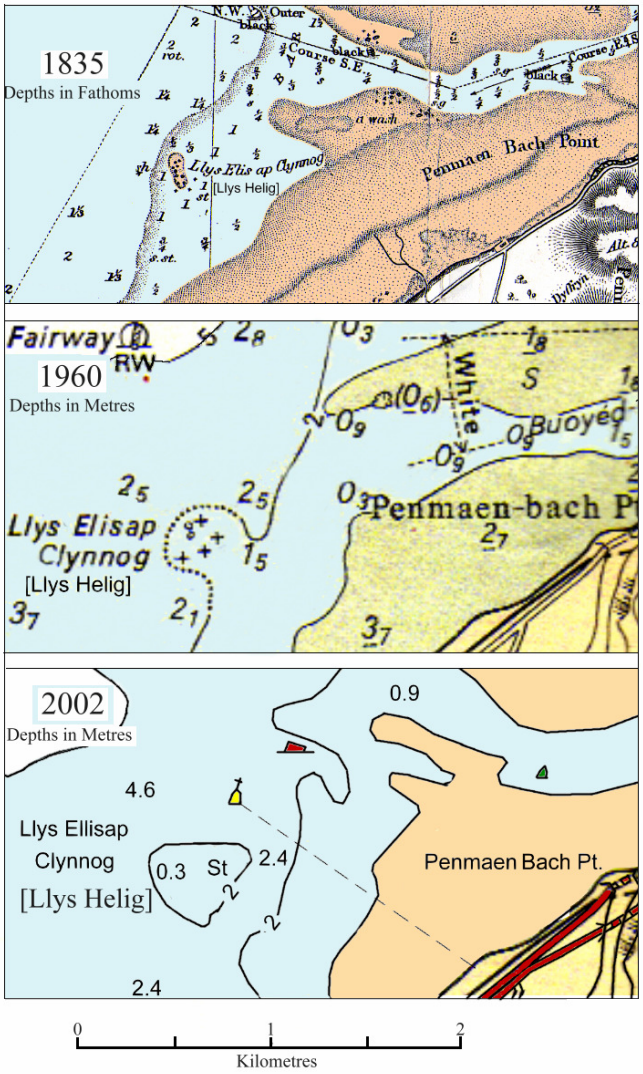
Rising Relative Sea Levels over Llys Helig Reef documented on Admiralty Charts.

The 1835 Chart shows Llys Helig Reef drying at Low Water.

The 1960 Chart shows just rocks breaking the surface at Llys Helig Reef at Low Water.

The depths shown are mainly from soundings taken in1890 and apart from soundings in the Conway Channel have not been updated. Other features have been updated with information from aerial photographs and other sources.

The 2002 Chart shows Llys Helig Reef covered to a depth of 0.3m at Low Water.



The versions of the name of the reef are a corruption of the full Welsh name Llys Hellig ap Glanog - the 'Barn' or Court of Helig the son of Glanog a 6th century Welsh Nobleman.

Castle Quays as R.S.L. & Time Frame Datum Points

The coastal Castles of Edward I were built close to the sea to enable them to be serviced by boat. The quay and moat at Beaumaris Castle built 1295 to 1330 are close to present R.S.L. and then, as now filled with tidal water [Taylor, A. 2004]. Although it is now landlocked, the present Castle staff, monitor and adjust moat and quay water levels at high tide with a sluice gate in a culvert leading to the sea. However around 1640 Sir Thomas Cheadle drained the moat, *'….and converted the same to meadowing and gardens…'* [Gwynne Jones, E 1948.]. It would seem that at that time the sea did not flood the area. In short, R.S.L. in1300 was at about present level but in the intervening years it was somewhat lower.

Beaumaris Castle

31.3.2010 high water at 1215hrs [approximate Mean High Water Spring Tides]. Photographs taken at 1130hrs.

The rising tide has filled the dock area and sea water is running though the spillway into the moat.

Harbour Quays as R.S.L. & Time Frame Datum Points

Port Penrhyn Menai Strait North Wales

Normal Tide 6.1.2011

Estimated 1.3m Storm surge 10.3.2008

The predicted tide for both days was close to M. H. W. S. Beaumaris - 3.6m above O.D.

Port Penrhyn was built in stages between 1790 and 1855 the later parts to a very high standard [Williams. M.E.1988]. In recent times sea level has risen above the quay on a number of occasions during storm surges by up to 0.4m and could potentially rise higher. This puts vessels alongside at serious risk of being damaged below water line on the knuckle of the quay. Experience gained of tide levels after 1790 would have ensured that the later high quality parts of the quay were not built with such a defect. This is further evidence that at that time R.S.L was obviously lower. Tidal surge levels can be difficult to ascertain as they often occur in windy conditions but in 1999 circumstances allowed accurate measurement. See Unusual Events – Tidal Surges.

Unusual Events – Tidal Surges

The effects of both negative and positive surges on R.S.L. have been observed, recognised and included in the study [Mariner's Handbook 1973]. While negative surges are too infrequent to

warrant fish weirs at a low level in the intertidal zone the possibility of positive surges plays a significant role in harbour design.

Positive tidal surges at Port Penrhyn

These events are only predictable in the short term and seem to be caused by very strong south westerly winds. On 24.11.1999 tidal predictions and weather forecasts suggested the possibility of a positive tidal surge at Port Penrhyn and the opportunity to document the event was taken. Measurements were taken at SH 59150 72800 on the outside western wall of the dock. At this point the quay is 4.65m above Ordnance Datum and the tide rose 0.25m above the quay or 4.9m above Chart Datum. The predicted tide approximated to M.H.W.S. at 3.5m above O.D.

Hence the tidal surge was 1.4m above predicted height and peaked 40 minutes after the time of predicted High Water. Under these circumstances boats were exposed to damage below waterline.

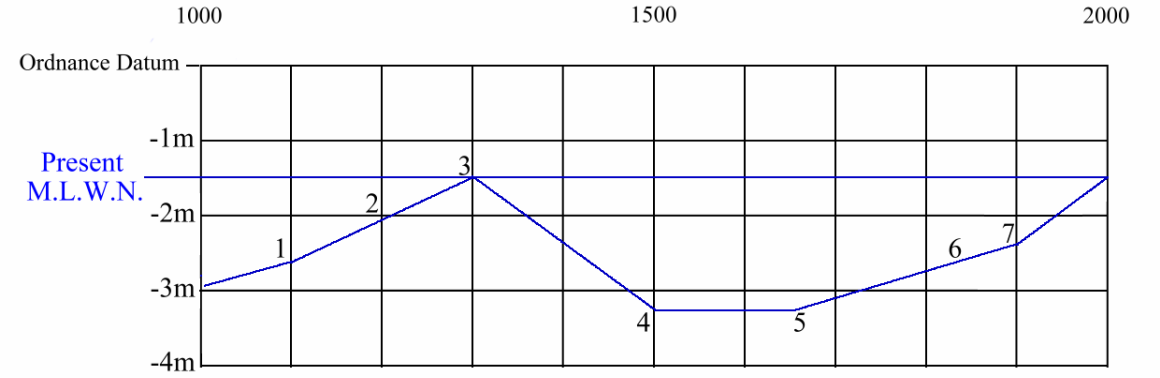
10.3.2008. Predicted High Water 1230hrs. A tidal surge at Port Penrhyn was photographed by Stuart Murray from 1310hrs to 1325hrs. An estimated surge of 1.3m peaked 45 minutes after H.W.

Summary

Multi-disciplinary studies of local relative sea level changes have produced a number of indications which may be expressed graphically.

Graph Prepared from Study Data

Showing variations in local Mean Low Water Neap Tides over the past 1000 years.



1. Norman takeover of Aberlleiniog and the gift of the Fish Weirs to St. Werburghs in Chester.

2. Possible build date of the Phase 3 modification of Gorad Trecastell.

3. Building of Beaumaris Castle Quay*1 and Gorad Maelgwyn Archival evidence.

4 & 5. Lower Mean Low Water Neap Tides indicated by C^{14} dates from Fish Weirs.*2

6. Port Penrhyn Harbour works and 1835 Admiralty chart levels at Llys Helig Reef and Gorad Rhos Fynach.

7. Photographs taken in 1913 at Llys Helig.

While it is possible to plot the levels back to 1300 AD with a reasonable degree of confidence, more data are required to date levels between that time and the earlier dated levels shown in the research of M.Roberts. [Roberts, M.J. 2006.]

*1 The 1300 level assumes that the tidal range then was the same as at present.

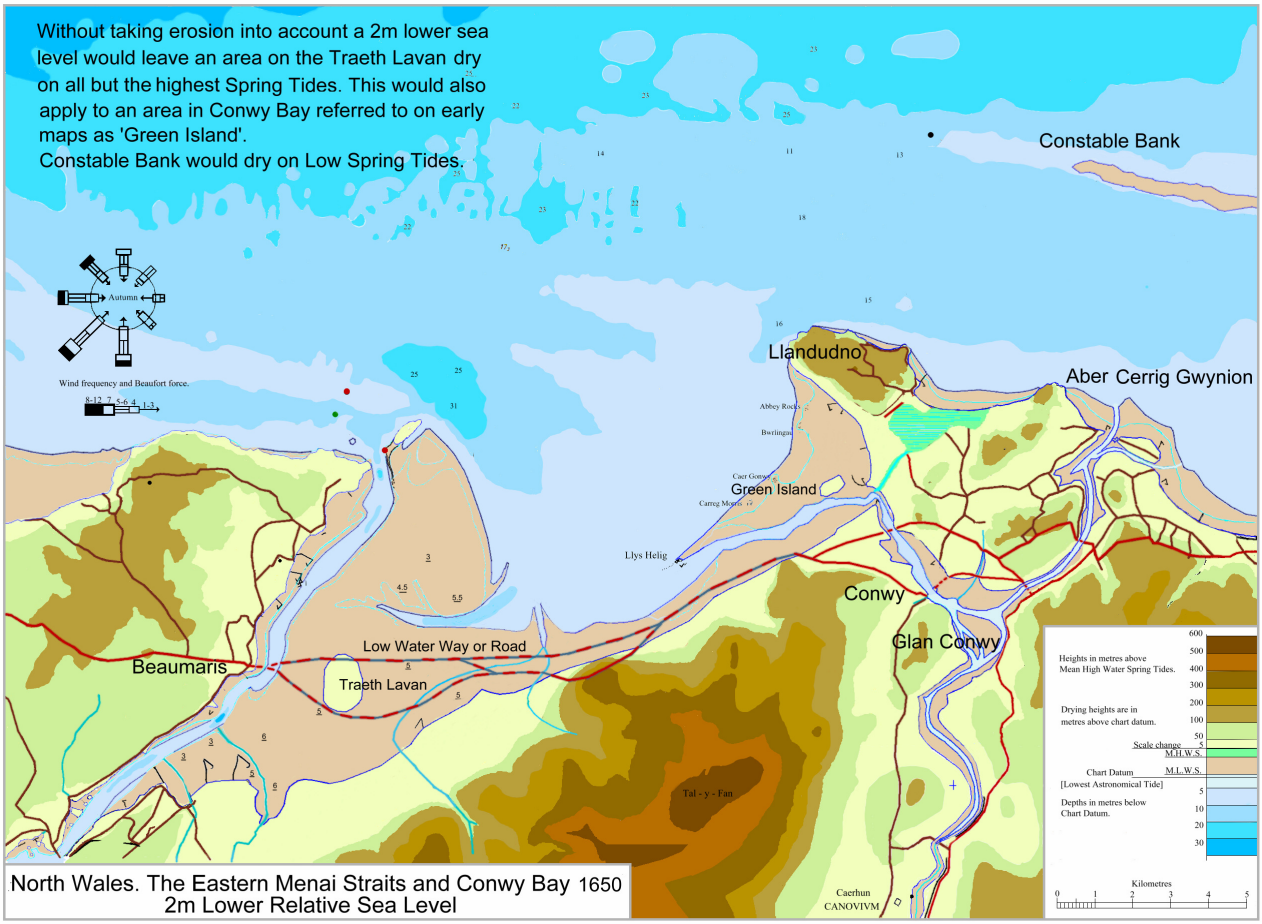
*2 The C^{14} dates would relate to the last time the Fish Weirs were repaired.

There are also data available for the preceding 1000 years but it is not possible to plot them with the same degree of confidence. With this caveat Phase 2 of Gorad Trecastell may well date to the arrival of the Augustinian Brethren around 600 AD and the Type 6 Phase 1 may date to before 500 AD and indicate M.L.W.N.T. more than 2.9m below present level. It is possible that the Type 6 Fish Weirs are of the *'Haecwer'* type or design from Saxon times. There seem to be traces of Saxon activity not too far away by sea at Rhuddlan; '*Town defences of Bank and Ditch. Possibly Saxon* [Hubbard,E. 2001]. The apparent type 6 at Llys Helig would traditionally date from before AD 560. The vertical position of the Aberlleiniog Type 6 indicates a relative sea level some 2.9m lower than at present. This places the sluice or part of the weir where the fish are trapped below Lowest Astronomical Tide level. This very significant observation prompted the commissioning of a highly accurate survey by a professional firm using G.P.S. equipment confirming results obtained by the author using an optical level. In other areas of the British Isles large fish weirs '*lie beneath several metres of water due to sea-level rises'* [Jecock, M. 2011].

While recognising that recent global sea level rise research has returned levels of 2.5mm / annum [Woodworth. P.2010] the above observations provide evidence that local R.S.L. fell after 1300 by at least 2m and has returned to the 1300 level at the present time. While a mechanism which could account for such a fluctuation obviously needs further research, its effects are measurable.

As yet only one date has been obtained from Aberlleiniog it is difficult to estimate the time span of this apparent relative sea level rise. The C^{14} date of 1674 was obtained from a fragment of wattle excavated from the most easterly of the two 'V' shaped Type 6 fish weirs but this date at first sight seems questionable as it implies a relative sea level rise of 1.7m in 300 years. However the Great Orme West Gogarth fish weir produced a C^{14} date of 1460 which, coupled with its position, suggests that sea level was at least 1.7m lower at that time than at present. In this case the sample was taken from a substantial wooden post. More samples for C^{14} dating could no doubt be obtained but due to the very limited time the lower parts of the intertidal zone are revealed – a few hours in a whole year – such excavations are somewhat difficult. However dating of the fish weirs of Aberlleiniog and those at other sites, especially where weirs are now so low on the beach as to render their effective operation totally impractical, would contribute in no small measure to the preparation of a definitive sea level curve for North Wales.

Relative sea level change curves (Lambeck.1955) plotted for Cardigan Bay would place the construction of the Aberlleiniog lowest fish trap in the early Bronze Age. This does not seem as likely as a Romano British date which could be suggested by a curve plotted by Lambeck for the East Lancashire coast and Morecambe bay. A sea level curve drawn for North Wales (Heyworth & Kidson.1989) would suggest a Mesolithic date for the lowest of the Aberlleiniog fish traps. However as the authors point out in the accompanying text, the curve was plotted using only two dates from before 4,000 radiocarbon years B.P. It also relied heavily on trends from curves drawn for sites well to the south. More local data is needed. Due to *'the paucity of local sea level data for the past 4000 years'* [Roberts, M.J. 2006] comparisons with data from other studies are not as yet possible.



The ‘Low Water Way’ and the more inshore beach route from Conwy to Beaumaris Ferry shown on the Collins 1695 chart strongly suggest lower Relative Sea Levels at that time.

Conclusion

A method of refining sea level curves for particular localities is examined. In an area with a rich marine cultural landscape, which possesses a large tidal range, it is shown that geoarchaeological investigation of natural features and artificial structures in the intertidal zone and shallow seas combined with cartographical studies can provide valuable clues to past sea levels.

The method has the potential for determining Relative Sea Level change over a long time frame and can provide valuable data for use in coastal management. Perhaps their most important contribution is to our understanding of relatively recent changes in sea level, which may allow an accurate estimation of future changes.

N.V. Campbell Bannerman 23.12.2011

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Glossary

Datum:

Ordnance Datum [O.D.] is a vertical Datum used by an ordnance survey. In Great Britain O.D. for the Ordnance Survey is Ordnance Datum Newlyn [O.D.N.] defined as the Mean Sea Level [M.S.L.] at Newlyn Cornwall between 1951 and 1921. From 1840 to 1921 O.D. was taken from the level of Victoria Dock in Liverpool.

Chart Datum [C.D.] is the level to which soundings and drying heights on a chart are referred. In practice it is the lowest height to which the tide is ever expected to fall. For various reasons this differs from location to location as does tidal range. Many sea charts include a table showing the relationship of local chart datums to Ordnance Datum Newlyn along with local tidal ranges.

Devensian. A cold stage between about 80,000 and 10,000 years before present.

Gorad, Goradau, pl. Welsh Fish Trap.

Holocene. The past 10,000 years.

Till [Moraine]. A poorly sorted, non-stratified material deposited by a glacier or ice sheet and containing a wide variety of grain sizes from clay to boulders. [Often called Boulder clay].