# A Statistical Review of Some Victorian Non-Ferrous Metal Mines of South Wales within Their European Context

by

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Disused metal mines are a memorable feature of my boyhood the more beguiling for their rarity in Hertfordshire. As a fourteen-year-old I visited the Roman Deep Mine whilst on a touring holiday with my parents. In those days one could freely enter the airy cavernous adits leading off the vast prehistoric gold quarry and view the decaying stylobates of pre-war crushers without also entering National Trust visitor centers, being charged and made to view videos.

The next year I looked forward to the mobility and independence of a Honda 50 and began to save for one. In the interim I fantasised about exploring the redundant metal mines of Mid-Wales that are gathered around Cwmystwith (SN 803746). I measured a motorable itinerary to that mine:- It is 202¼ miles from Ware to Cwmystwith via Bicester and Rhayader.

At the start of the year I planned to travel our family moved to Scotland so when I came of age to ride my motor-bike I took a trip to Kildonan instead. I never visited Cwmystwith.

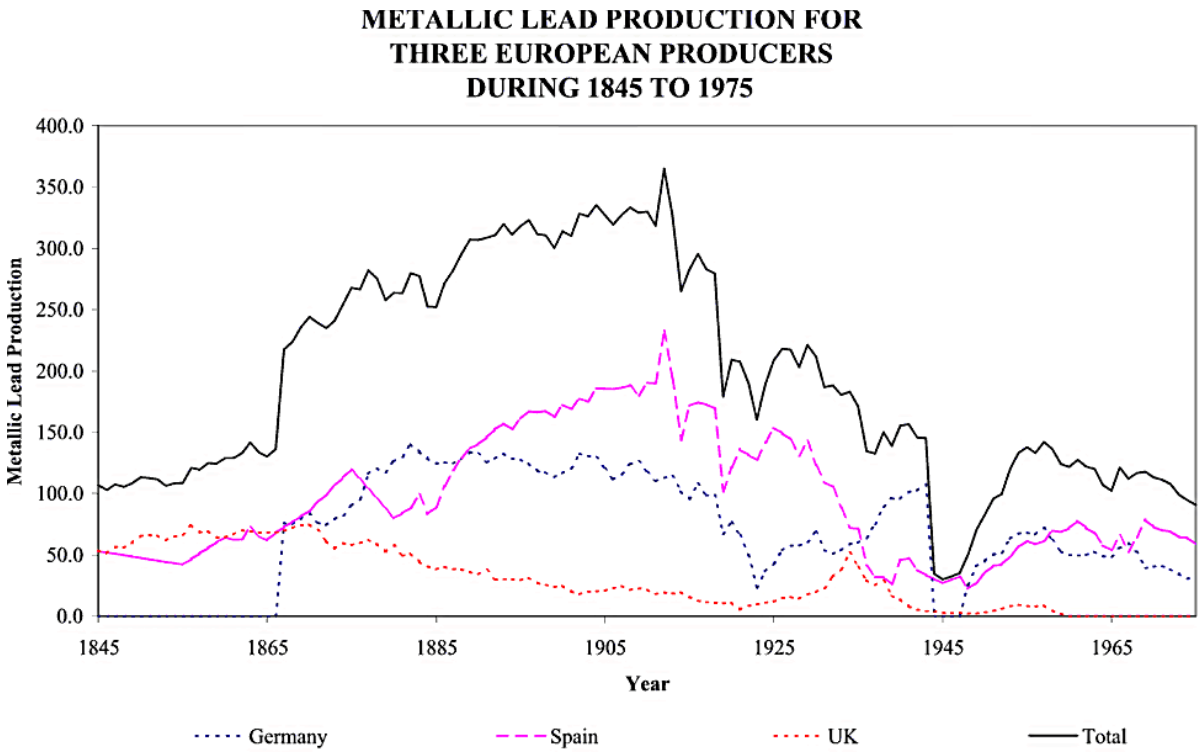
Not that is for another twenty-seven years, for I visited it at the lunch-time of Tuesday 5 July 1994, the first anniversary of my visiting the Mandale Mines during a lovely walk through Lathkill Dale.

There is relatively little there now save the enormous screes of fractured shale. There are no traces of galena like the fist-sized lumps you could pick up outside English mines twenty-five years ago. Such trophies have yielded to the age of mass undergraduacy and the car-borne amateur. Cultural vestiges have largely succumbed to the combined onslaught of wind, rain and safety officers. Cwmystwith's great galvanised iron concentration mill of 1899 was demolished since 1987[1] on safety grounds but you can still find the odd plate or rod of excellent Victorian wrought iron continuing its design purpose of support.

That afternoon I visited the Llywernog Silver-Lead Mine Museum (SN 732810) near Ponterwyd, where I purchased the excellent "Metal Mines of Southern Wales"[2]. The Welsh production statistics for this study are taken from p57, p58 and pp 92 and 93 of that publication.

Some Plumbiferous Powers

Statistical time series are readily available for the non-ferrous productions of selected European states. The UK commenced to collate national statistics in 1845 and Mitchell[3] has used this as the datum of his historical series for Germany, Spain and the UK. I have charted these histories for lead, with annual totals, on the diagram headed "Metallic Lead Production for Three European Producers".




Early Spanish figures were given upon the semi-decade and it was quite clear that these figures abridged an annual account. Accordingly I have linearly interpolated these intervals and used the estimates in totalisation as well as graphing. Greater uncertainty was engendered by the fact that German figures are for "crude ore" prior to 1923. If Mitchell had written "concentrates" I would have estimated the lead content of earlier production as 86.6% for normative galena. In these circumstances, however, I compared prior and posterior five-year averages whilst allowing for the pre-war Silesian ore contribution implied by the 1922 German figure to arrive at an estimated lead content of 78.9%. This compares with the known average UK lead content between the years 1845 and 1914 of 73.412%. Despite the high expected margin of error I scaled the pre-1923 German figures by this fraction to attain consistency. I have not attempted to address the problems inherent in the definition of the word "Germany" and exemplified by the foregoing discussion of Silesian contribution. It is of course

the case that Ireland also seceded in 1922: In its case from the UK. My understanding is that Irish secession had a small effect upon UK lead and zinc productions at the time, though a comparable treatment over the years 1845-1975 should include post-war Irish production which is significant on the European scale.

Since 1845 the three powers have brought to grass some 25.4376 million tonnes of lead metal. The recent UK consumption ( according to the CSO Annual Abstract of Statistics for 1991 ) is 0.3003 million tonnes, so the post-1845 total is about eighty-five years supply for Britain. Germany accounts for a share of 35.2%, Britain a mere 15.3% and Spain 49.5%. Total mean production was a mere 194,200 tonnes per annum of which the UK share was 17.5%. During the period 1845-1975 the Coefficients of Variation for Germany, Spain and the UK were respectively 39.3, 52.9 and 68.8 reflecting the fact that the British contribution was not only small but unsteady.

Since boyhood I have embraced the inchoate ideas that not only was Britain the dominant Victorian lead producer, but that more generally lead-winning was the bellwether of industrialisation. Both fallacies are given the lie by the Mitchell statistics. Britain had lost the lead to both Germany and Spain by 1865 at the latest and whilst Spain has yielded as much metal as Germany and Britain together Spain is only now becoming an industrial power of the modern type whilst Britain ceased this last ten or twenty years since to be an "essentially industrial" nation.

Careful scrutiny of the Mitchell figures yields some even more remarkable facts. Until the turn of the century Spain complemented the second-rank producer ( usually Germany ) tending to linearise total supply growth. In the Twentieth-Century, however, a pan-European decline set in, possibly due to the maturation of overseas producers as well as substitution of the material. To illuminate this decline it would be interesting to compare these time series with those for Australia, the USA and Russia and also to study the evolving role of synthetic resins and other hydrocarbon-derived chemicals as plastic materials and pigment bases.

War has had dramatic effects on West European lead-mining, but not in the way you may think. The First World War caused a previously buoyant production to *slump* in all three nations and production then bounced unstably to a level of half the pre-war output in 1924. The coming of Primo de Rivera and then the Civil War sent the Spanish mines into a catastrophic decline which bottomed at 26000 tonnes in 1939 and failed to perk-up significantly during the Second World War. British production maintained a steady 60000 tonnes per annum till 1870 when a secular decline set in to reach a low of 5300 home tonnes in 1921. During the early 1930's a remarkable swan-song occurred reaching a peak of 51900 tons in 1934 a level last visited by the British in 1881. A sudden

bust ensued and astonishingly the British halved and then halved again their lead production during World War Two.

At the end of Hitler's War, West European lead-mining reached its nadir of 30000 tonnes of metal per annum. Since that time the re-instatement of the pre-war regime of linear decline has been accompanied by a revival of the Victorian Hispano-German complementarity.

To view the longer historical perspective we may note that the eighteenth-century wars of The Spanish and Austrian Successions and The Seven Years War severely depressed the price of lead at London, possibly because of disruption to the important French market, a guess substantiated by bullish post-war recoveries. Only the Napoleonic and Crimean Wars have increased the lead price, the latter by as much as 35%. The inelasticity of UK lead production is, however, demonstrated by the 20% rise in ore mined between 1853 and 1856, whilst exports of refined metal increased 21% over a shorter period and imports commenced their galloping climb only after the War's end.

Annual ore tonnages are recorded for the Nantymwyn Mine in Carmarthenshire between 1775 and 1797. Though there is strong fluctuation in the series there is no apparent correlation with the American War of Independence or with the incipient conflicts with Revolutionary France.

## The Scale of Production in South Wales

South Wales is a minor plumbiferous region in a minor lead-mining country.

Production statistics since 1845 are expressed in terms of "lead concentrates" which I over-generously interpret as normative galena ( PbS ) with a lead content of 86.6% by mass.

Throughout this paper masses and volumes of lead yields are computed upon the assumption that lead concentrates are "normative" pure galena, PbS. Accordingly, lead is assumed to be 86.6% by mass of the weighed concentrates. This is not , of course, entirely realistic because a residuum of gangue and water inevitably remains admixed with the ore. Cerussite is assumed negligible. Solid-solution galena contaminants like silver can account for as much as 0.045% weight of the PbS in the South Wales province, ( based upon 15 troy ounces of silver in the short ton of pig lead ). The average lead content of UK ore refined between the years 1845 and 1914 was 73.412%[4], but this excludes "up-chimney" losses of maybe four percent of the metal. Readers who wish for a more conservative picture of lead yields are therefore invited to scale the illustrative South Wales lead masses and volumes which follow by 0.84771.

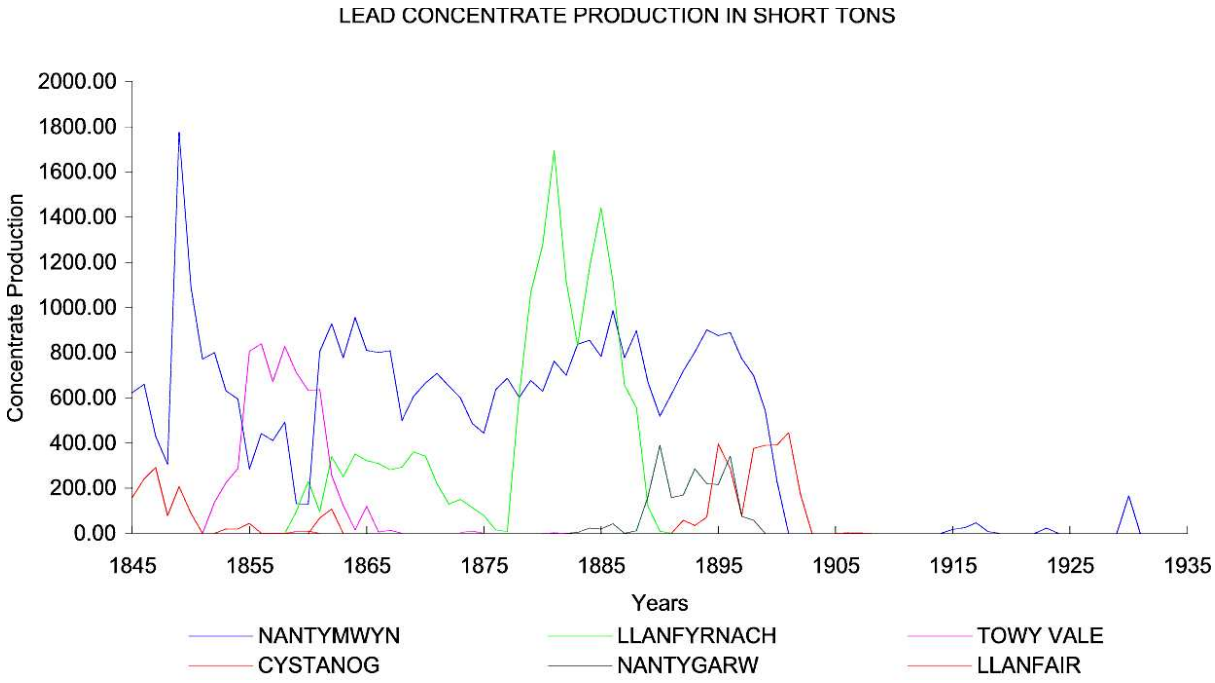
Considered in these terms the eighteen principal South Welsh mines brought some 54756 tonnes of metal to grass during 1845-1930. The Powell

Duffryn Standard Lowliner Gloucester LTF13 is a modern railway platform wagon designed to take ISO 2.9-meter shipment containers through The Channel Tunnel[5]. The British have made forty-five of these trucks and each can bear thirty-six tonnes. Let us say that twenty formed a train for shipping this production from Avonmouth next week. Then thirty-four round trips would do. Perhaps you find it handier to think in volumetric terms. Then this metal would condense to a lump 16.9 meters cube, the volume of 12008 four-draw filing cabinets. More tellingly, these 54756 tonnes of lead would satisfy 1991 UK demand for just six days and sixteen hours.

By far the most prolific and consistent mine was that in the sequestered vale of Nantymwyn, Carmarthenshire (SN 787445). It brought up 30213 tons of metallic lead after 1845 ( 3 days and 16 hours 1991 UK supply ) or 69960 if you include production back to 1775.

At the opposite end of the scale the seventeenth-ranked mine Abergwessin ( SN 832503), Breconshire ( maybe five miles away from Nantymwyn ) produced 6.285 tonnes of lead metal representing 1.38 four-draw filing cabinets. This is accounted for by six short tons of concentrate for 1866 and two for 1846. Issued share capital in 1846 was £10000 and the revenue at dispatch about £71 for twenty years of fitful labor. I find it impossible affectively to apprehend the poverty and dejection of the miners who would make such pathetic scratchings of The Earth: No wonder many preferred The Patagonian Desert.

Inspection of the graph "Lead Concentrate Production in Short Tons" shows the relative consistency of Nantymwyn compared with such evanescent stars as Vale of Towy (SN 437199) and Llanfyrnach (SN 225316) which produced respectively 4966 and 12297 tonnes of lead from 1852 to 1867 and ( chiefly ) 1878 to 1890. Three little mines show some intermittent working.




Zinc production was a minor ( no pun intended! ) after-thought at Vale of Towy, Llanfyrnach and Nantymwyn. Total production was 2857 metal tonnes, 996 four-draw filing cabinets in volume or 8 hours 20 minutes 1991 UK supply.

In the 1850's there was erratic copper production at four little mines. Copper metal raised would not have exceeded eighty-six tonnes in total, less than twenty-four filing cabinets in volume and fifteen minutes 1991 UK supply.

The most singular mine in South Wales is the Roman Deep gold mine at Dolaucothi, Carmarthenshire (SN 663030). Known to have been exploited by the Romans it enjoyed brief revivals in the Edwardian Era and in 1936. These Modern episodes raised 12.25 kilograms of metal. This forms a volume of 1.35 VHS video cassettes. Say that a typical 18-carat wedding ring is a 5mm broad D-sectioned band with an internal diameter of 15mm. You could make 15694 of those with the 12.25 kilos of Roman Deep gold. This is not entirely of academic interest because a mine elsewhere in Wales has just taken to subsidising gold production by showing tourists around whilst using its metal to keep three ethnic jewelers in work.

## Grouped Frequency Distributions

I have ranked the eighteen principal South Welsh lead mines in order of lead concentrate production since 1845 with a view to educing some distributional characteristics.

Zipf's Law is a statistical rule to the effect that for any member of a

population the quotient of the logarithm of its size divided by its rank position is a constant. Zipf's Law is supposed to approximate many statistical distributions, classically the populations of human settlements in the USA and Continental Europe.

In algebraic terms Zipf's Law may be expressed as:-

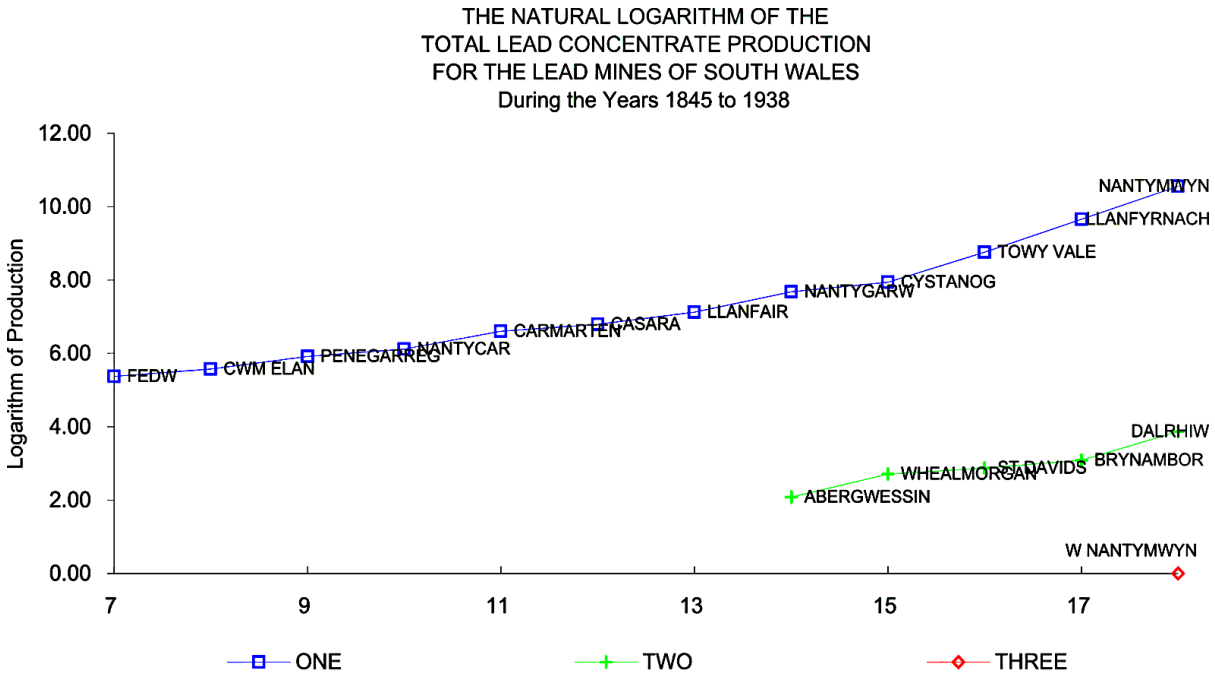
$$K = \frac{\mathrm{Log}_n(s_i)}{r} \qquad \textbf{Eqn.1}$$

where K = a Constant
$s_i$ = The Size of Entity i
r = The Rank Position of Entity i

r is largest for the biggest entity, so in our lead mine study r=18 for Nantymwyn and r=1 for West Nantymwyn.

The question is this: Does Zipf's Law hold good for these mines? Strictly, the answer is "No".

The graph headed "The Zipfian Parameter Logn (Production)/Rank for The Lead Mines of South Wales" displays the Zipf's Law "constant" for the eighteen mine productions whilst preserving rank relativities. Clearly, only the largest mines show any constancy ( $\log_n(s_i)/r \approx 0.6$ ) whilst the rule breaks down entirely for Statistical Province Two. I have fitted cubic regression curves to the two substantive provinces to clarify the discrimination between Statistical Provinces which is explained in greater detail below.



Refer to the graph "The Natural Logarithm of the Total Lead Concentrate Production for the Lead Mines of South Wales". Note the striking linearity of the eighteen Logn(Tonnage)/Rank Position values. This implies a relation of the form:-

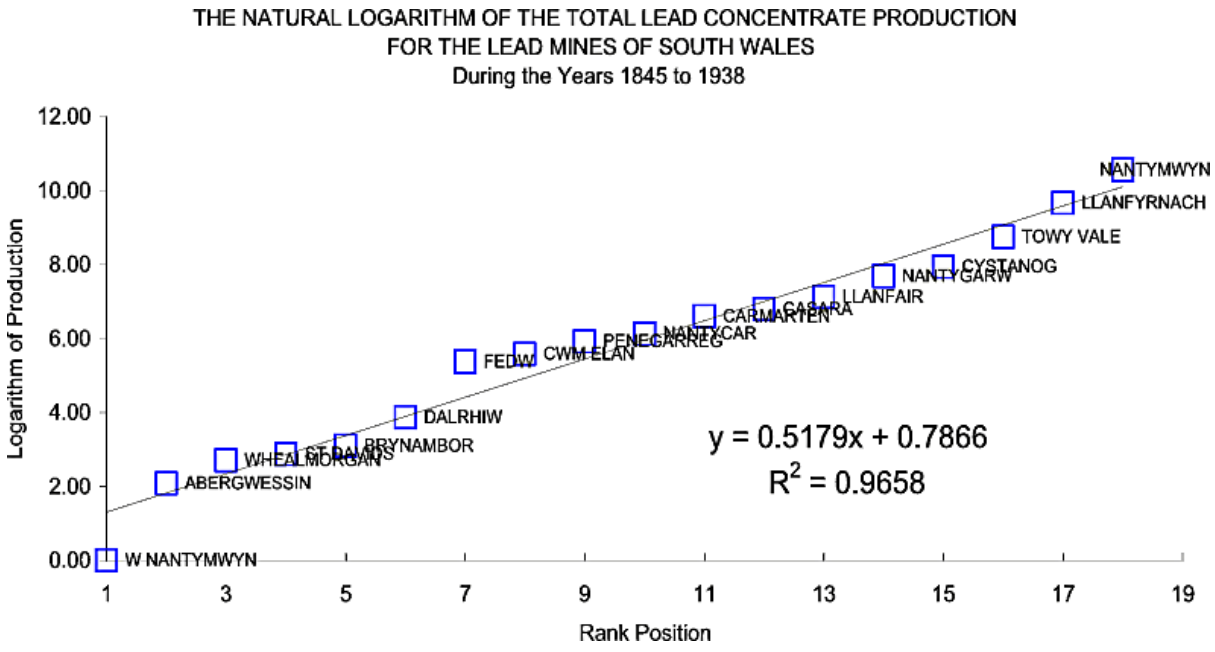
$$\mathrm{Log}_n(s_i) = a + br \qquad \textbf{Eqn.2}$$

where a = The Intercept
b = The Grade

or:-

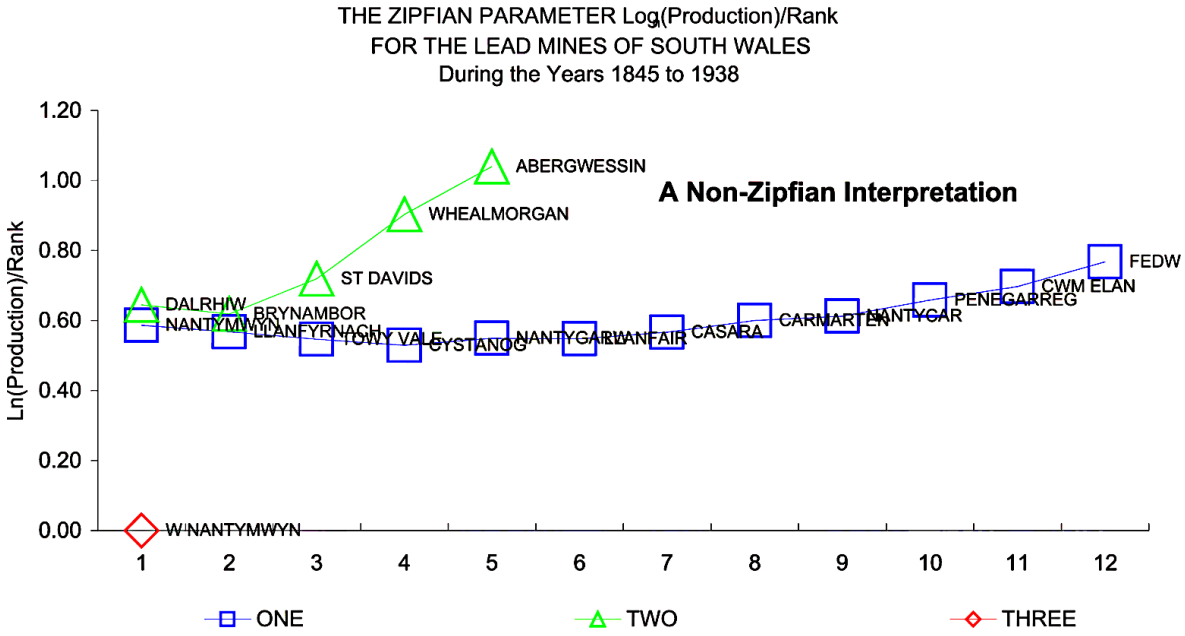
$$\frac{\mathrm{Log}_n(s_i)}{r} = \frac{a}{r} + b \qquad \textbf{Eqn.3}$$

where a and b are constants characteristic of this group of entities ( respectively about 1.29 and 0.47 ).

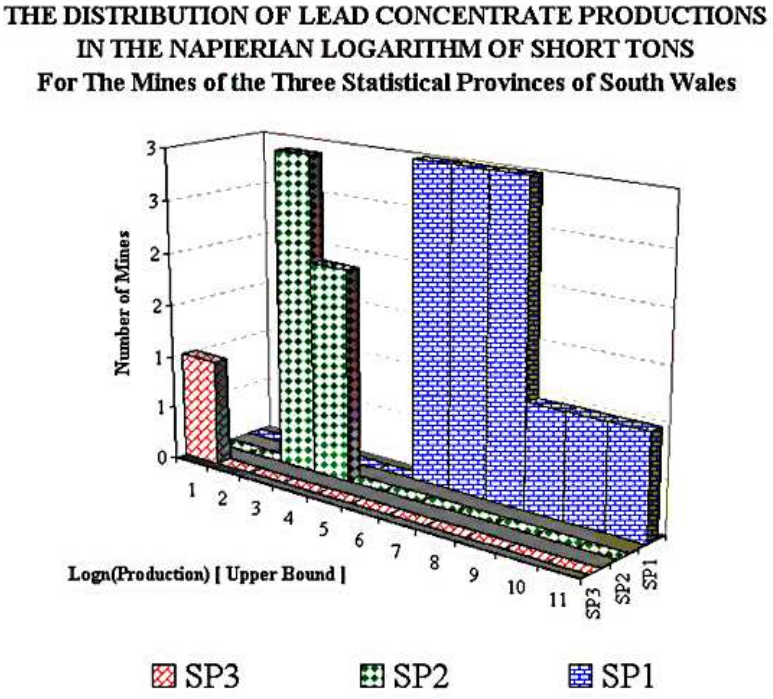



This is a semi-logarithmic Rank Size Rule[6] but closer scrutiny of the graph shows a pronounced discontinuity between Dalrhiw and Fedw plottings. Indeed there appear to be two distinct STATISTICAL PROVINCES of lead mines. Province One includes the larger mines of Nantymwyn, Llanfyrnach, Vale of Towy, Cystanog, Nantygarw, Llanfair, Casara, Carmarthen United, Nantycar, Penegarreg, Cwm Elan and Fedw. Province Two is a smaller group of five little mines Dalrhiw, Brynambor, St David's, Wheal Morgan and Abergwessn. Province Three is a degenerate class including only the West Nantymwyn trial

which raised just one ton of concentrate. Clearly the two substantive series' plots have an ogee-like or cubic curvature and the graph annotated "A NON-ZIPFIAN INTERPRETATION" illustrates the close fit of cubic regression curves which appeared to reflect those fitting the Zipf Parameter relationships.




These statistical provinces are mirrored in the three distinct and separate grouped frequency distributions illustrated in "The Distribution of Lead Concentrate Productions in the Napierian Logarithm of Short Tons".




I do not know why these two distinct statistical distributions appear. They are not due to geological heterogeneities at the system level, because to the best of my knowledge all these mines are promiscuously mixed within Lower Palaeozoic argillaceous provinces, unless one or two of the Eastern diggings are in the Devonian. More recondite factors are obviously at play. Some of the old Welsh captains alleged that significant paydirt only occurred in lodes striking North-South; East-West structures proving poor. This suggestion requires more careful research with the relevant maps and records. If the segregations are primarily due to economic or engineering factors then relatively large ( but still piffling ) reserves may remain at the Statistical Province Two mines. The European statistics show that wars, slumps, dictatorships and other macropolitical vagaries have the greatest adverse effects upon ore production, not scientific factors. On the micro scale whim, retirements, shareholder panics and ( in rural Wales ) power supply problems could slay a mine in its prime.

Furthermore, it is sometimes alleged that the cost book financing common amongst Victorian metal mine companies encouraged short-termism including the hasty stripping of the richest ore pockets and the deliberate neglect of known sparse reserves. Joint stock enterprises are, by way of balance, frequently derided for over-capitalised surface installations intended to impress prospective shareholders. There is a strong suspicion of such thinking at the Bryndyfi works of the 1880's ( SN 683934 ) and in more recent memory one recollects the splendiferous ConsGold office block at the 1970's revival of Wheal Jane.

## Conclusion

The history of European non-ferrous ore production reflects changing social and economic conditions and almost certainly secular changes in the patterns of World Trade and available technology.

Using lead ore and its product as our exemplars we can see that since 1845 British mines have contributed 3894500 tonnes of metallic lead, 15.3% of the European total of 25437600 tonnes. Of this latter total the South Wales mines contributed some 54756 tonnes or 0.2%, enough for thirty-four train-loads. Trivial amounts of zinc and copper were raised and the Carmarthenshire gold raised by The Moderns could be put in a ladie's shoulder-bag and carried away by a fit woman.

Elementary statistical treatments resolved the South Wales lead mines into two distributions differing not merely by mine size but also in distribution shape: The reasons for this statistical segregation are unknown. Further research is recommended to illuminate the factors which have apparently permitted differential mine yields and to see if similar factors and dispersions extend to other orefields.

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