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A PETROGENETIC STUDY OF GRANITOIDS IN NORTH-EAST FINISTERE, BRITTANY, FRANCE - A PRELIMINARY STUDY

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The north-west Finistère region lies to the north of the North Armorican Shear Zone and forms part of the "Domaine Domnonean", interpreted as a Precambrian terrane which contains some early Proterozoic units (Roach, 1977). These Brioverian sedimentary rocks were subjected to deformation and metamorphism in both the Cadomian and Hercynian orogenies. During the latter the Ploudalmezeau, Aber Ildut, Kernilis and Landunvez granites were emplaced.

These are dominantly two-mica granites, either megacrystic in part (Aber Ildut), or equigranular. The alkali feldspars have variable structural states. Accessory phases present include monazite and ilmenite.

The major element geochemistry indicates that these granites are peraluminous, possess calc-alkaline characteristics and show linear decreases in Fe, Ca, Mg, and Ti with increasing silica. Among the trace elements Zr, Y, Sr, and Ba decrease with increasing silica, whilst Rb rises exponentially.

Preliminary Rb/Sr isotopic results confirm the Hercynian ages of all four granites, although they may have undergone perturbation by later hydrothermal activity. Sm-Nd systematics reveal a strong igneous (I type) component in the source materials of these granites, supported by other chemical and petrographic criteria. However, other criteria suggest they may be of "S"- type origin.

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INTRODUCTION

The area studied lies north of the North Armorican Shear Zone (NASZ) and forms part of the "Domaine Domnonean" which is thought to be a Precambrian terrane containing early Proterozoic basement units (Roach, 1977). It consists of Brioverian sedimentary rocks laid down as early as 750Ma to 540Ma (Leutwein, 1968; Guerrot and Peucat, 1990; Pasteels and Doré, 1982). These sediments were subjected to deformation and metamorphism during the Cadomian (late Precambrian to Cambrian) (Cogne, 1970) and subsequently during the Hercynian orogeny (Peucat *et al.,* 1978). It was during this later episode that the area was intruded by a series of granitic intrusions, four of which, the Ploudalmezeau, Kernilis, Aber Ildut and Landunvez form the subject of the present study.

GEOLOGICAL SETTING AND FIELD RELATIONS

The geology of north-west Finistère is covered by the 1:80 000 Service Geologiques National Brest sheet No. 57 and comprises several Brioverian schist and gneiss units (Figure 1) whose present geological features were produced during the Bretonic phase of the Hercynian orogeny. Metamorphism reached amphibolite facies (Chauris *et al.* 1972) and resulted in the formation of migmatites and associated anatectic granite bodies.

The Orthogneiss de Tréglonou is considered to be pre-Brioverian (Chauris, 1966), possibly early Proterozoic (locally called the Icartian), and almost certainly forms the basement. This is succeeded by amphibolite facies rocks which had pelitic and psammitic precursors: these are locally named the Gneiss de Lesneven and the Amphibolites Quartzitiques de Lannilis (Chauris, 1966). During Hercynian times, the Aber Ildut, Ploudalmezeau and Kernilis granites were emplaced into these older rock units. These granites, in common with others of similar age in Northern Brittany, are thought to be postorogenic, whereas the Landunvez granite to the north of the Porspoder-Plouguerneau Lineament is thought to be related to the migmatitic rocks.

The Aber Ildut and Ploudalmezeau granites form arcuate discordant plutons (Figure 1). Their northern limits are defined by the Porspoder to Plouguerneau Lineament, and their southern boundary is formed by the pre-existing tin-bearing granite of Saint Renan; their western boundary lies off-shore and their eastern extent is curtailed by the pre-existing gneissic complexes of Lesneven and Tréglonou, which separate the Kernilis granite from the Aber Ildut complex to the west.

The age relationships of the various granites are seen near the Pointe de Penvir, where the Landunvez granite cuts the Amphibolite Quartzitiques (Portsall Diorite of Roper, 1980) and approximately 0.5 km to the south-west of Porspoder, where the Ploudalmezeau granite cuts the Aber Ildut pluton. The Landunvez pluton is cut by the Adamellite de Ste. Marguerite.

TABLE 1: Mean modal mineral proportions of the Hercynian granitoids from north-west Finistère.

	Modal Proportions						
Granite	Quartz	K-feld	Pl-feld	Biotite	Muscovite	Tourmaline	Minor Phases
l'Aber Ildut Outer Facies	33.6 ± 1.6	20.1 ± 1.4	34.9 ± 1.6	3.1 ± 0.6	7.5 ± 0.9	0.7 ± 0.3	-
l'Aber Ildut Inner Facies	24.6 ± 1.6	17.5 ± 1.4	43.0 ± 1.8	15.7 ± 1.3	trace	-	-
Landunvez	26.0 ± 1.3	37.4 ± 1.5	29.2 ± 1.4	3.4 ± 0.6	1.8 ± 0.4	-	2.2
Ploudalmezeau - Kernilis	33.2 ± 1.3	24.0 ± 1.1	30.6 ± 1.2	1.9 ± 0.4	7.7 ± 0.7	-	2.6

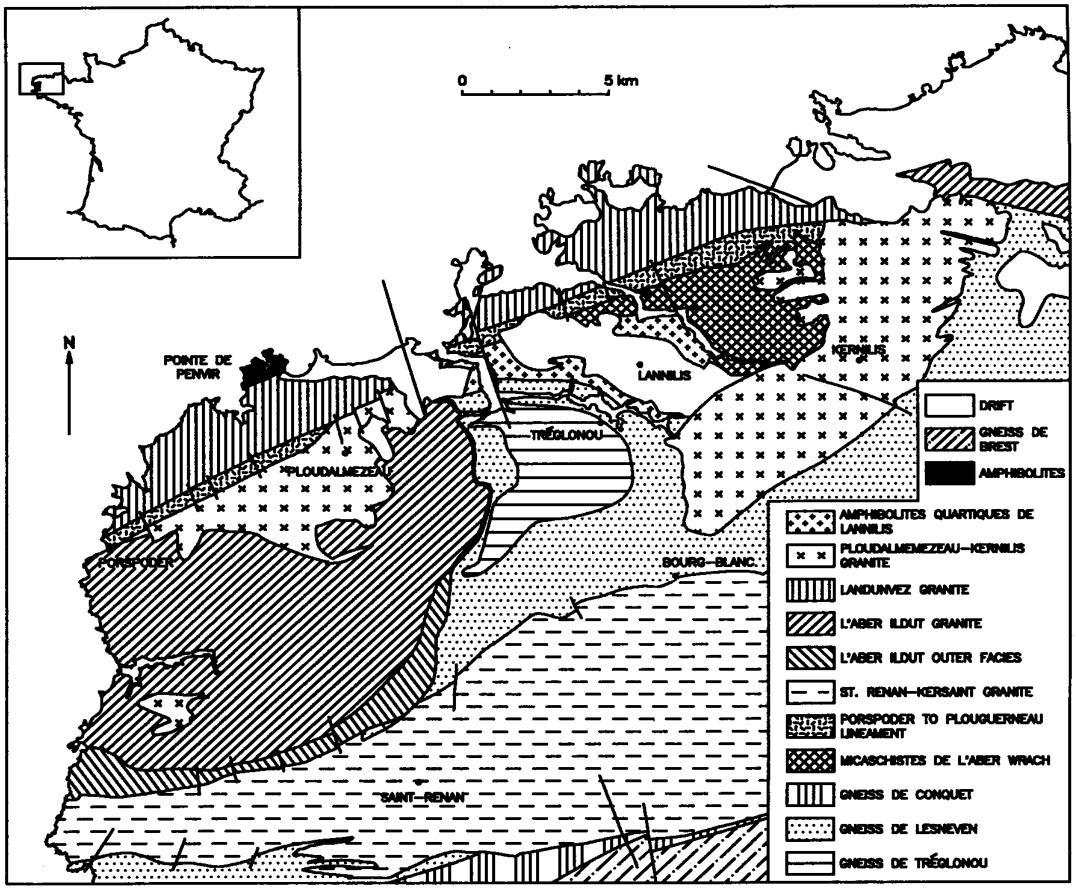

Figure 1: Simplified geological map of the Aber Ildut Massif, north-west Finistére (after Chauris et. al. 1972).

Both the Aber Ildut and Ploudalmezeau plutons are cut across by various microgranites.

PETROGRAPHY AND MINERALOGY OF THE GRANITES

The Aber Ildut granite comprises two facies, an outer equigranular rim, frequently tourmalinised and an inner, red megacrystic unit containing an abundance of fine-grained mafic inclusions. Some of these inclusions are spherical and measure up to 60 cm in diameter, but most are elliptical, measuring some 20 cm along the major axis. In the granite, the megacrysts are of K-feldspar, which together with biotite, plagioclase feldspar, quartz, apatite and more rarely muscovite, are the main constituents. Subsequent sub-solidus hydrothermal activity has produced alteration products such as chlorite and epidote/clinozoisite.

The Ploudalmezeau and Kernilis plutons are lithologically and mineralogically identical. They are two-mica equigranular granites with isolated patches of tourmalinisation. Infrequent garnets are observed in the Kernilis outcrop. Both these granites are inclusion-free. The Landunvez granite contains abundant garnets and two micas, some of the latter have been re-crystallised following a secondary phase of mineralisation. The mineralogy of the Ploudalmezeau and Kernilis granites is similar to that of the Aber Ildut, but both show a significant increase in the amount of muscovite relative to biotite.

Modes plotted on a Streckeisen (1976) diagram show that the Aber Ildut granite lies in the granodiorite field, while the remaining plutons plot in the granite field.

59 samples of alkali feldspars were separated: 21 from the Ploudalmezeau and Kernilis plutons, 22 from the Aber Ildut pluton and 16 from the Landunvez granite (Figure 2). Initially, it was thought that the distribution of the different polymorphs could be related to the mappable sub-units. The methods of Stewart and Wright (1968) were used to determine the cell parameters of

TABLE 2: Mean values of major and trace element concentrations of the Hercynian granitoids of north west Finistère.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total	Fe_2O_3T
Ploudalmezeau-Kemilis	73.48	0.16	14.68	0.58	0.59	0.03	0.12	0.49	3.43	4.9	0.31	1.02	99.92	1.23
Landunvez	72.13	0.25	14.88	0.96	0.88	0.04	0.31	1.12	3.12	5.37	0.18	0.76	100.04	2
l'Aber Ildut	69.12	0.49	15.48	1.09	1.8	0.06	0.81	1.62	3.46	4.89	0.28	0.86	99.96	3.09

	Cr	Cu	Ga	Nb	Ni	Pb	Rb	Sr	Th	V	Y	Zn	Zr	Ba	La	Ce	Nd	Cl	S
Ploudalmezeau-Kemilis	16	1	22	14	4	34	359	64	13	10	13	43	71	199	7	23	15	151	89
Landunvez	15	4	20	12	4	53	248	209	18	21	17	37	146	536	19	44	. 21	560	157
l'Aber Ildut	20	6	23	21	8	29	328	210	22	43	19	54	177	472	41	84	33	294	121

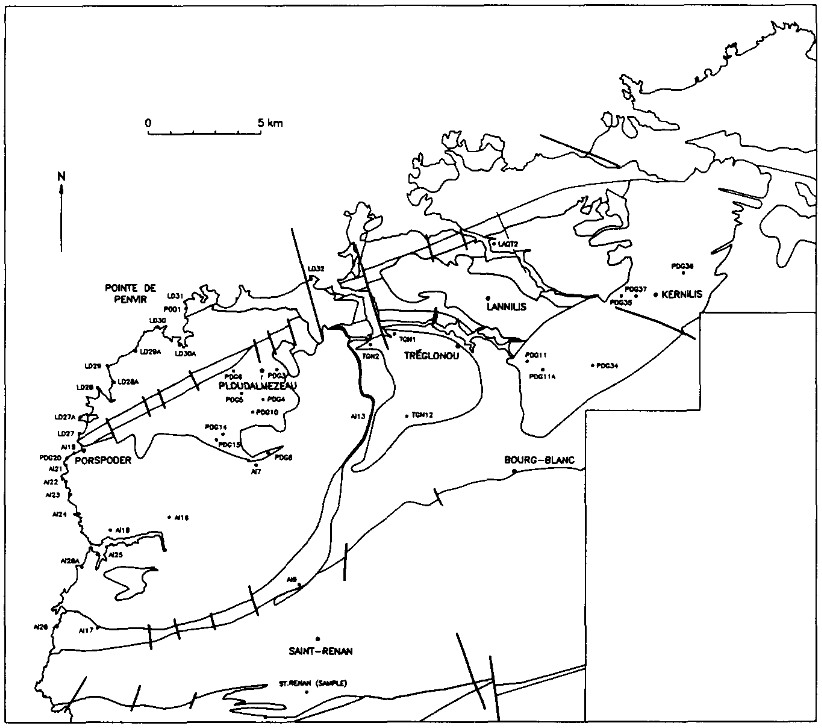

Figure 2: Location map for geochemical and feldspar samples, northwest Finistère.

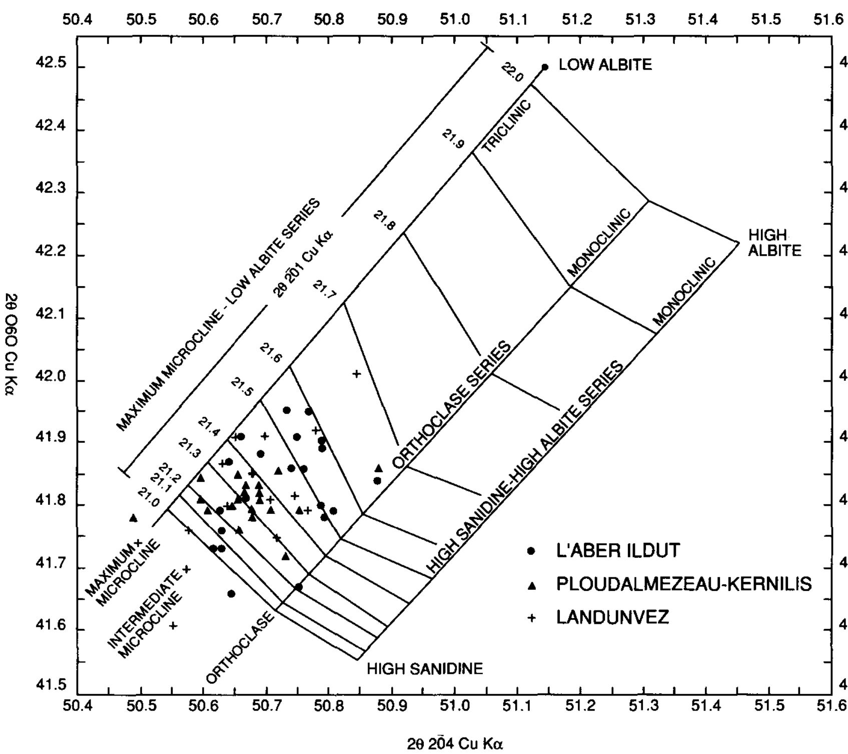

Figure 3: Composite plot of structural state of alkali feldspars from the Aber Ildut, Ploudalmezeau-Kernilis and Landunvez granites.

the feldspars and hence their structural state. At high temperature (>525°C Goldsmith and Laves, 1954), orthoclase feldspar is homogeneous with respect to Na and K components and possesses a monoclinic unit cell. On cooling, unmixing occurs and at temperatures of c. 300°C microcline feldspar becomes triclinic. Thus, the structural state of feldspar can provide information on crystallisation temperatures and subsequent cooling history of the host granites.

To illustrate the spatial variations in triclinicity and their possible correlation with intra-pluton chemical evolution, composite plots of the structural state of feldspars (Figure 3) are shown together with plots of Rb/Sr against SiO_2 for each pluton (Figure 4).

PETROCHEMISTRY

Some 78 samples from the four plutons were collected for major and trace element analysis: twenty-seven from the Ploudalmezeau and Kernilis granites, nineteen from the

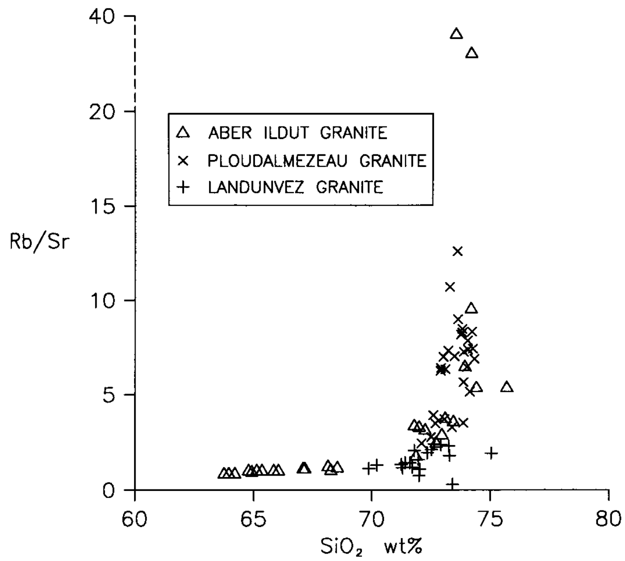

Figure 4: Plot of Rb/Sr against silica for the Aber Ildut, Ploudalmezeau-Kernilis and Landunvez granites.

Landunvez and thirty-two from the Aber Ildut pluton together with samples of xenoliths, cross-cutting micrograniites, country rocks and other granites from Northern Brittany, making a total of 127 samples (Table 2). The Aber Ildut, Ploudalmezeau Kemilis and Landunvez granites show a range of SiO_2 contents from 63-74 wt%. All rock types are peraluminous with Al_2O_3 : $CaO + Na_2O + K_2O$ ratios of 1.52, 1.7 and 1.74 respectively. The comparable ratio of the Portsall Diorite is 1.42 within the range of normal calc-alkali rocks.

Major element variation diagrams, (Figure 5) show the expected linear decrease in Fe, Ca, Mg and Ti with increasing SiO_2, whereas there is not this negative covariation with Na and K. Such linear trends provide evidence for possible fractionation from a more basic parent. Alternatively the dilution effects of increasing SiO_2 with reduced proportions of other major oxides can produce similar trends. Chemically, the two inclusions from the Aber Ildut pluton are consistently distinct, perhaps indicating a different source from the granites.

Trace element plots (Figure 5), again illustrate linear trends. Zr, Y, Sr and Ba all decrease with increasing SiO_2, while Rb increases exponentially with increased SiO_2.

ISOTOPE STUDY

A detailed exposition of the isotope study will be published elsewhere, but it can be stated that these granites are Hercynian and that the Landunvez pluton was emplaced first:

Granite	Age	M.S.W.D.	Initial Sr ratio
Ploudalmezeau-Kernilis	310+/-8.49	12.78	0.706984+/-0.001458
Aber Ildut	297.24+/-11.68	4.64	0.705740+/-0.000429
Landunvez	326.5+/-9.15	12.07	0.706178+/-0.000357

The Epsilon values of Sr and Nd provide evidence about the protolith material of the granites, and the source region of the inclusions/xenoliths within the Aber Ildut pluton:

Epsilon (ε) Nd - Sm Data

Granite	Average values Nd	Average values Sm
Ploudalmezeau-Kemilis	-4.4	+36.2
Aber Ildut (Inner facies)	-3.1	+15.4
Aber Ildut (Outer facies)	-3.8	+33.6
Landunvez	-3.8	+22.4

TECTONIC SETTING

The majority of samples from the Ploudalmezeau-Kernilis granites and the outer facies of the Aber Ildut plot in the alkali-calcic high-Himalaya leucogranite field (Figure 6), while the remainder, including the Landunvez granite, generally fall within the range of normal calc-alkali rocks.

A spidergram plot (Figure 7) of a range of trace elements showing profiles of each of the granites together with the Portsall Diorite virtually all plot in the post-collision granite field (Pearce *et al.,* 1984). In the Nb against Y plot (Pearce *et al.,* 1984) all the granites plot in the syn-collision field (Figure 9). It has been established by Harris *et al.* (1986) that high Rb low (Nb + Y) (Figure 8) identifies not only syn-collision granites, but also post- collision crustal melts and these granite samples straddle the boundary between fields representing upper crustal melts and volcanic arc/post-collision. Rb/Zr vs SiO_2 has been used (Harris *et al.,* 1986) as an indicator of crustal melting. Zr is thought to be residual during anatexis and a linear increase in Rb/Zr with increased silica possibly indicates a high crustal contribution. The granites in the present study show a linear rise at low silica contents, with an exponential rise in Rb/Zr at higher SiO_2 values, which may confirm a crustal component to the magma.

DISCUSSION

The field relationships between the Ploudalmezeau-Kernilis granite and the Aber Ildut pluton show that the former is younger, although isotope data do not distinguish them. It is possible that intrusion of the younger granite has caused isotopic re-equilibration. Similarly the intrusive effects of the Adamellite de Ste. Marguerite granite on the Landunvez pluton and the micrograniites on the Ploudalmezeau pluton suggest that the ages give the date of the younger intrusion, rather than the times of emplacement of the primary host granites.

These reheating effects are observed in the alkali feldspars (cf. Figures 3 and 4), where the high temperature monoclinic feldspars correspond with the most evolved part of the Aber Ildut pluton, while more triclinic forms increase towards the Porspoder to Plouguerneau lineament (Figure 3). Nilssen and Smithson (1965) have shown that high temperature monoclinic feldspars are more prominent in more mafic rocks in a pluton, whereas the low temperature triclinic form occurs in rocks richer in volatiles. This relationship is apparent in the Ploudalmezeau/Kernilis granite (cf.Figures 3 and 4), but in the Aber Ildut pluton it is rather the reverse, a feature that may suggest a role for subsequent re-heating. Tilton *et al.* (1964) showed that the structural state of alkali feldspars is susceptible to re-heating, and demonstrated this through the intrusive effects of a quartz monzonite on feldspars contained within a pre-existing gneiss. At distances less than 550 m from the contact with the monzonite, the feldspars within the gneiss were of the high temperature, monoclinic form, whereas at distances between 550 m and 1200 m both monoclinic and triclinic forms occurred. Parsons (1978) also showed that metasomatism resulted in the growth of feldspar megacrysts and delayed their inversion from monoclinic to triclinic.

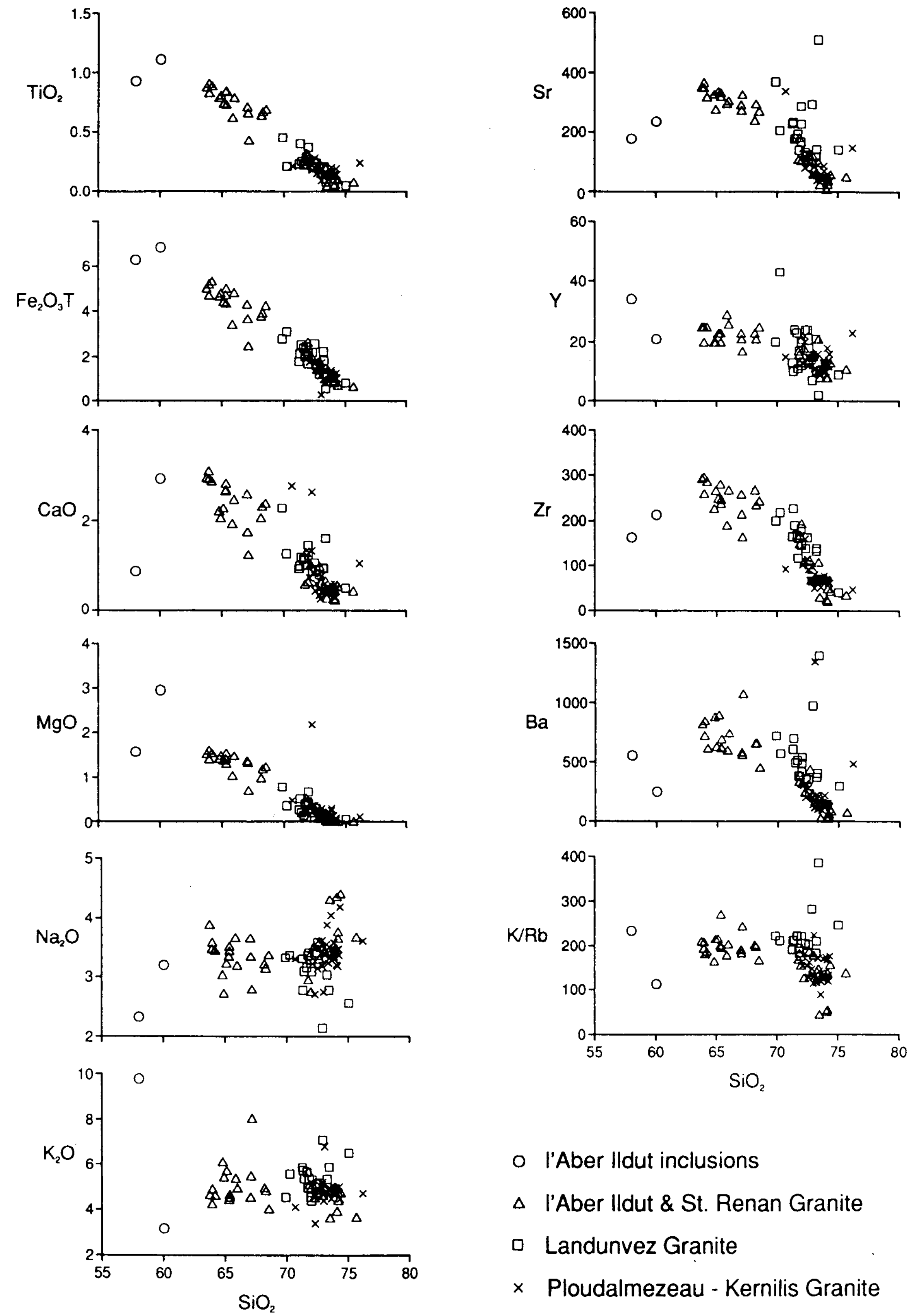

Figure 5: Silica variation diagrams for samples from Ploudalmezeau-Kernilis, Aber Ildut and Landunvez granites with inclusions from Aber Ildut. Oxides in weight %, trace elements in ppm. All Fe calculated as Fe_2O_3.

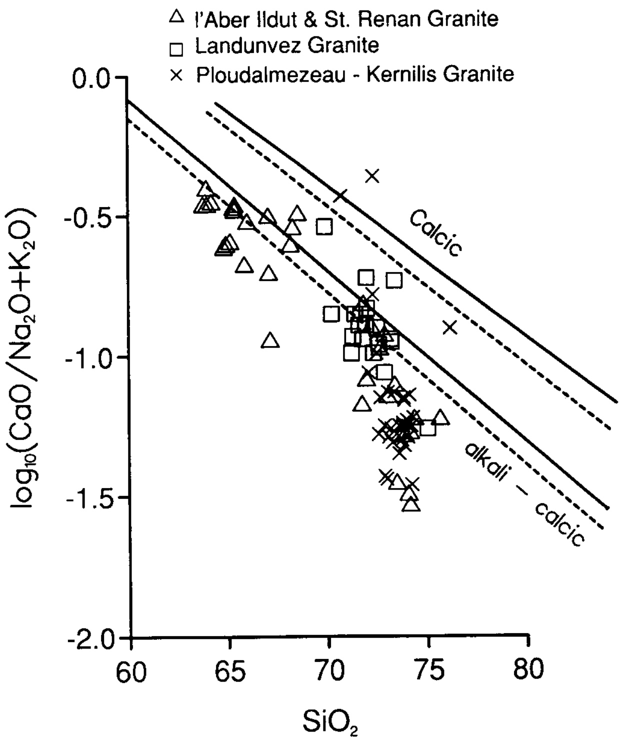

Figure 6: Plot of log10 (CaO/Na_2O+K_2O) against silica for samples from Ploudalmezeau-Kernilis, Aber Ildut and Landunvez granites. Broken lines indicate boundaries of cak-alkali field. Solid lines define field of Andean andesites, (Brown, 1982).

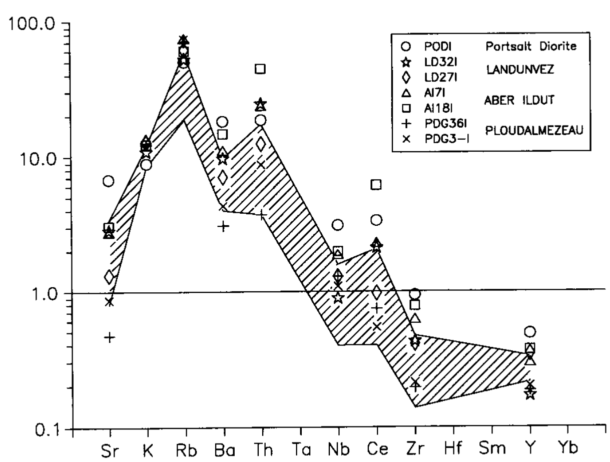

Figure 7: Geochemical patterns for granite samples from north-west (SiO_2 = 63 - 74%) normalised against Ocean Ridge Granite (O.R.G.) (after Pearce et al. 1984). Lined field = volcanic arc/post-collision granite.

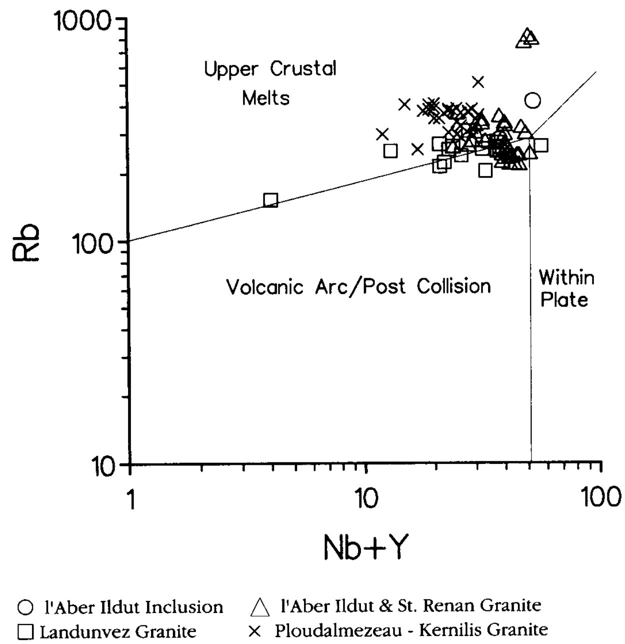

Figure 8: Plot of Rb against (Nb + Y) for granite samples from north-west Finistère. Field boundaries from Pearce et al. 1984.

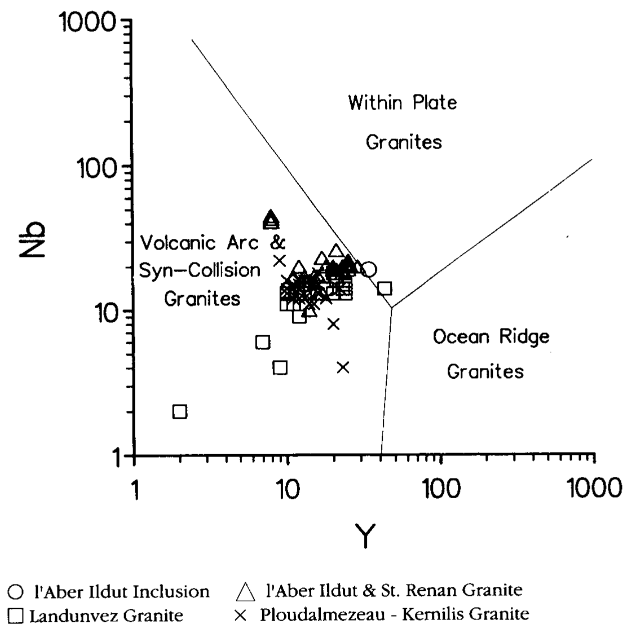

Figure 9: Plot of Nb against Y for granites from north-west Finistère. Field boundaries from Pearce et al. 1984.

The effects of re-heating are therefore clearly demonstrated, with the heat source originating from the younger intrusive. All samples in the Landunvez granite (Figure 8) are microcline and to a variable extent triclinic. There is a paucity of positive trends and an absence of any direct relationship between structural state, rock composition and extent of magma evolution (cf. Figures 3 and 4).

The major and trace element Harker plots (Figure 5) show that all the granites lie on a single trend: the Ploudalmezeau- Kernilis pluton is the most evolved, the Aber Ildut is the least evolved and the Landunvez occupies an intermediate position. The existence of such a trend is compatible with derivation of all three from a common source. However, having established that the Landunvez pluton is the oldest, it follows that the granites cannot have resulted from a single fractionation process, but may have been the subject of separate magmatic/melting events. The geochemical evidence establishes fairly conclusively that the inclusions/xenoliths contained within the Aber Ildut granite are of a different source from any of the proximal granites. Further work, currently in progress, with Pb isotopes may help to clarify the position.

Granite magmas are frequently images of their source rocks (Chappell and Stephens, 1988) and the peraluminous nature of the granites is reflected in the degree of alumina saturation which is also present in the Portsall Diorite. The trace element arrays of the granites and the Portsall Diorite (Figure 7) provide supporting evidence for the Portsall Diorite or a body of similar composition as a possible source.

The connection between the Hercynian granites and the Porsporder to Plouguerneau lineament was referred to by Chauris (1966).The present study also suggests that the emplacement of the granites is in some way related to this. Whether or not the lineament has provided a passage for the magma is uncertain, but work by Halden (1982) in eastern Finland suggests that preexisting areas along such shear zones become dilated as the result of lateral movement, resulting in zones of tension, which coupled with magmatic pressure facilitates the emplacement of the plutons. It is hoped that further field work in proximity to the lineament will clarify the position.

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REFERENCES

BROWN, G.C. 1982. Calc-alkaline intrusive rocks: their diversity, evolution and relation to volcanic arcs. In: *Andesites*. Ed: R.S. Thorpe, John Wiley and Sons, 437-461.

CHAPPELL, B.W. and STEPHENS, W.E. 1988. Origin of infracrustal (I-type) granite magmas. *Transactions of the Royal Society ofEdinburgh, Earth Sciences,* **79**, 71-86.

CHAURIS, L. 1966. *Bulletin de la Carte géologique de la France,* LXI, 9-30.

CHAURIS, L., HALLEGOUET, B., BABIN, C., PLUSQUELLEC, and MORZADEC, P. 1972.*Cartegéologique au 80000 feuille Brest 3e édition.*

COGNE, J. 1970. Le Brioverien et le cycle orogenique cadomien dans le cadre des orogènes fini-pré-cambriens. *Colloque international sur les corrélations de Pré-cambrien,* CNRS RABAT 1970. Edition du Service géologique du Muroe 1972, 193-313.

COGNE, J. 1972. Le Massif Amoricain et sa place dans la structure des socles ouest-européens. L'arc hercynien Ibéro-Amoricain. In: *Histoire structurale du Golfe du Gascogne,* Techniqs edit, **1**, 1-23.

GOLDSMITH, J.R. and LAVES, F. 1954. The microcline-sanidine stability relations. *Geochimica et Cosmochimica Acta,* **5**, 1-19.

GUERROT, C. and PEUCAT, J.J. 1990. U-Pb geochronology of the late Proterozoic Cadomian orogeny in the northern Amoricain Massif, France. In: *The Cadomian Orogeny*. Eds: R.S. D'Lemos, R.A. Strachan, and C.G. Topley. Geological Society of London, Special Publication, **51**, 13-26.

HALDEN, N.M. 1982. Structural, metamorphic and igneous history of migmatites in the deep levels of a wrench fault regime, Savonranta, Finland. *Transactions of the Royal Society of Edinburgh,* Earth Sciences, **73**, 17-30.

HARRIS, N.B.W., PEARCE, J.A. and TINDLE, A.G. 1986. Geochemical characteristics of collision zone magmatism. In: *Collision Tectonics*. Eds: A.C. Ries and M.P. Coward, Geological Society of London Special Publication, **19**, 67-81.

LEUTWEIN, F. 1968. Géochronologique et evolution orogenique pré-cambrienne et hercynienne de la partie nord-est du Massif Amoricain. *Sciences de la Terre, Mémoires,* **11**, 1-84.

NILSSEN, B. and SMITHSON, S.B. 1965. Studies on the Precambrian Herefoss granite. 1, K-feldspar obliquity. *Norsk Geologisk Tidsskrift,* **45**, 367-396.

PARSONS, I. 1978. Feldspars and fluids in cooling plutons. *Mineralogical Magazine,* **42** 1-17.

PASTEELS, P. and DORÉ, F. 1982. Age of the Vire-Carolles granite. In: *Numerical Dating in Stratigraphy*. Ed: G.S. Odin, John Wiley. 784-790.

PEARCE, J.A., HARRIS, N.B.W. and TINDLE, A.G. 1984. Trace element discrimination diagram for the tectonic interpretation of granitic rocks. *Journal of Petrology,* **25**, 956-983,

PEUCAT, J.J., LE METOUR, J. and AUDRAN, C. 1978. Arguments géochronologiques en faveur de l'existence d'une double ceinture métamorphique d'âge Siluro-Dévonien en Bretagne méridionale. *Bulletin de la Société Géologique de France,* **7**, t2, 163-167.

ROACH, R.A. 1977. A review of the Precambrian rocks of the British Variscides and their relationships with the Precambrian of N.W. France. In: *Le châine varisque d'Europe moyenne et occidentale.* Colloque intemationale du Centre National de le Recherche Scientific, **243**, 61-79.

ROPER, H. 1980. Polyorogenic evolution of the western Pays de Leon, Finistère, France. Ph.D. Thesis (unpublished) University of Keele.

STRECKEISEN, A. 1976. To each plutonic rock its proper name. *Earth Science Reviews,* **12**, 1-33.

TILTON, G.R., DAVIS, G.L., HART, S.R., ALDRICH, L.T., STEIGER, R.H. and GAST, P.W. 1964. The microcline- orthoclase transition within a contact aureole. *Annual Report of the Geophysical Laboratory.* 1963-1964, 253-256.