Age and tectonic implications of the Baie d’Audierne basic-ultrabasic complex

Major deformational and metamorphic events in the south-armorian metamorphic belt of south Brittany have been considered to be either Cadomian and Variscan\(^1\) or Ordovician-Silurian (Ligerian) and Variscan\(^2\) in age. Geological interest in southern Brittany is, at least in part, focused upon the blueschists\(^3\) and the basic-ultrabasic complexes of the area. The largest of these basic-ultrabasic complexes is that of the Baie d’Audierne group (Fig. 1). Although lacking suitable material for direct radiometric or stratigraphical dating, several indirect attempts have been made to date this group, using field data. These are briefly outlined here. It is proposed that the deformational and metamorphic history of this complex is entirely Variscan in age. The implications of this conclusion for the recently proposed plate-tectonic model of Cogné\(^4\) are discussed.

The south-armorian metamorphic belt comprises a suite of non-fossiliferous, pre-Stephanian sediments, commonly ascribed to the late Proterozoic Brioverian\(^5\), which have been folded, metamorphosed and intruded by basic and ultrabasic rocks, granites and granite gneisses\(^6,7\). In the Baie d’Audierne region (Fig. 1), two divisions within the metamorphic rocks, an upper and a lower suite separated by an unconformity have been recognised\(^8,9\). It is thought that the lower suite was folded and metamorphosed in the amphibolite facies (kyanite grade) during the late Proterozoic Cadomian orogeny\(^10\) before the deposition of the upper suite. The upper suite commenced with the deposition of a basal sedimentary series, the Languidou gneiss. Ordovician to Carboniferous sediments lie offshore of the Baie d’Audierne; their relationships to the upper suite is, however, uncertain\(^11\). In the Baie d’Audierne, the upper suite is cut by the Pors Poulan granite gneiss (Fig. 1) which has yielded a whole rock Rb/Sr isochron at 334 ± 8 Myr (\(\lambda_{187} Rb = 1.47 \times 10^{-11} \text{ yr}^{-1}\)). This radiometric date has been interpreted as the magmatic cooling age of the granite. Subsequently, the whole sequence, upper and lower suites and the intruded Pors Poulan granite, was folded by upright folds on east–west axes and metamorphosed in the albite-amphibolite facies during the Variscan orogeny. Late Variscan granites intrude all the metamorphic rocks and are probably associated with other south-armorian granites emplaced into rocks of Upper and Lower Palaeozoic age\(^11\).

During recently completed fieldwork in the area where Cogné and Peucat defined the upper and lower Brioverian, in the Baie d’Audierne region (Fig. 1), I was unable to recognise any unconformity. The upper and lower suites throughout the area show a common structural and metamorphic history. In addition, the Languidou gneiss, interpreted by Cogné\(^12\) as a metagranulitic and used by Peucat\(^13\) to support the postulated unconformity, is thought to be an intrusive granite containing partially assimilated xenoliths of country rock. The supposed "pebbles" are deformed feldspar porphyroblasts and quartz-feldspar segregations. The Languidou gneiss shows the same pre-tectonic relationship to the surrounding metasediments as the Pors Poulan gneiss. This pre-tectonic relationship also applies to an association of gabbron and peridotite (now amphibolite, garnet–orthopyroxene and serpentine, ascribed by Peucat to his lower suite) which intrude the metasediments. Following the intrusion of these ultrabasic to granitic rocks, the entire complex (the Baie d’Audierne group\(^14\)) was isoclinal folded and metamorphosed in the amphibolite facies, up to sillimanite grade, with the development of an axial planar schistosity. This early schistosity was deformed by rare isoclinal folds and
on the Ile de Groix (420–370 Myr) (ref. 17) as inferred from Rb/Sr mineral and whole rock data ($\lambda_R^7 = 1.42 \times 10^{-11}$ yr$^{-1}$). A K/Ar 335 Myr mineral age has been suggested for this blueschist metamorphism$^{14}$, which may, however, represent a later thermal event. In view of the spatial association of the above mentioned radiometric ages, rock types and metamorphic facies, it is possible to place the rocks of the Baie d’Audierne within the context of recently proposed tectonic models for south Brittany$^{16,20}$. Such a tectonic context is necessarily confined to the south of the South Armorican Shear Zone due to the uncertainty concerning the movement history on this major tectonic line (P. Jegouzo, personal communication) and, therefore, the questionable validity of direct correlation between the south american metamorphic belt and central or north Brittany, the British Isles and so on.

The dominant strike trend in the Baie d’Audierne region is 070° (ref. 6); that of the migmatite belt to the east–south east is 110–120° (ref. 1). A gently curved arc can be envisaged, truncated by the late Variscan granites and mylonites of the South Armorican Shear Zone. Before the emplacement of these granites and the subsequent shear zone movement, the Baie d’Audierne group, which extends westwards to the edge of the submarine continental shelf$^7$, would have extended to the east–north east, around the northern flank of the migmatite belt (Fig. 2). Whether or not the migmatite belt extended south of the present outcrop of the Baie d’Audierne group cannot be ascertained, as this position is occupied by a large, late Variscan granite (Pont l’Abbé). It is with this pre-late Variscan granite configuration in mind that the tectonic significance of the Baie d’Audierne group is discussed.

At, or even before, ~420 Myr ago, blueschist metamorphism was taking place to the south of a high temperature–medium pressure belt within which anatexis eventually occurred. Relict areas of older granitic material (Port Manech and Cap Sizun gneisses) within the western part of the high temperature zone$^{1,6,17}$ suggest that the migmatite belt lay on, or immediately to the south of, continental crust (Fig. 3). The metamorphic belt therefore comprised an Andean type margin with a northward dipping subduction zone$^{19,20}$.

Metamorphism and deformation of this margin during the Ord–Silurian (Ligerian) orogeny was related to subduction and the eventual arrival of northward moving continental material (Fig. 3), now lying immediately south of the blueschists (micaceous, granites and undifferentiated Palaeozoic sediments of the South Brittany continental shelf$^{22,23}$). In the Baie d’Audierne area, sometime between the initiation of subduction (~420 Myr) and 334 Myr ago, rifting occurred.
Spike responses of 'non-spiking' visual interneuron

Our understanding of information processing in nerve nets has been modified by the concept of graded signal transmission. Descriptions of non-spiking interneurones in insects1–3, and the demonstration of graded synaptic transmission3 have contributed to this development. In the fly visual nervous system, second and higher order interneurones are known, which apparently do not produce action potentials3–4. We show here that at least eight individually identifiable movement-sensitive cells, which have the characteristic properties of non-spiking interneurones5 will generate spikes with imposed hyperpolarisation. Their graded mode of operation is due to maintained refractoriness. This applies selectively to neurones, which belong to either of two anatomically, and physiologically distinct classes. Other cell types in the same preparation generate spikes spontaneously.

The third visual neuropil of flies contains two conspicuous sets of directionally-selective movement-sensitive neurones5–10—an array of 10 'vertical cells' (VS1–VS10) which respond to vertical movements in the ipsilateral visual field, and an array of three 'horizontal cells' (HS1–HS3) which respond to horizontal rotary movements in the visual field of the two eyes1–4. Figure 2a–f shows some of the characteristic responses to visual stimuli of the neurone VS1 depicted in Fig. 1. Its membrane potential in the dark is about −41 mV, modulated by sparse synaptic activity (Fig. 2a). Illumination of the receptive field causes a small depolarisation and a marked increase in 'noise' (Fig. 2b). When a striped pattern moves upwards in the receptive field, the cell is hyperpolarised, and the noise reduced (Fig. 2c). With downward movements it is depolarised, and the noise increased (Fig. 2d). Clockwise (Fig. 2e), or counter-clockwise (Fig. 2f) horizontal movements are ineffective. The movement responses are largest at a pattern speed of 2 periods per s, thus corresponding to the velocity-dependent optomotor behaviour of intact flies11–13. It is possible to record this kind of electrical activity from any one of the VS- or HS-cells for more than 1 h, without ever

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**Fig. 1 Neurone VS1 of the blowfly Calliphora erythrocephala, as reconstructed after procion yellow injection, and serial sectioning.** The right half of the fly's brain is shown from behind. Neuronal areas are white, tracts and perikaryon layers are shaded. The retinotopic projection of the ipsilateral visual field into the plane of the third visual neuropil (lobula plate) is indicated. VS1 belongs to a set of 10 large movement sensitive neurones, which occupy the caudal face of the neuropil. Their dendritic arborisations are in the lobula plate, the somata are in the caudal surface layer, and their axon terminals are close to the oesophageal canal (EC). Field axes: a–p, antero-posterior horizontal; d, dorso-ventral (vertical); arrow: site of penetration.