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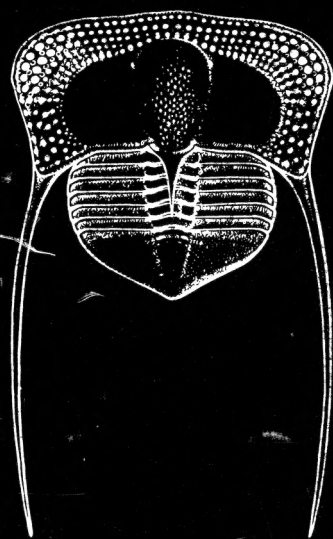
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THE ORDOVICIAN OF THE ARMORICAN MASSIF (FRANCE)

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ABSTRACT. A review is presented of recent progress in knowledge of the Ordovician of the Armorican Massif. Attention is drawn to the confusion that has resulted from indiscriminate use of lithological units which have previously been considered as chronostratigraphical units. In order to avoid confusion, the use of formations is introduced with the intention of translating local successions into lithostratigraphical terms. The lithological successions and the faunas collected are outlined to provide a clear statement of the degree of correlation at present possible between successions in different areas of the Massif Armoricain, with comments on elements of ambiguity that still remain. The results are expressed in thirteen representative columns and a correlation chart. Following the regional studies, a comprehensive picture (excluding the southern area) is proposed, outlining the development of the Ordovician transgression; the main features of sediments which are of shallow-water type and comprise sandstones, siltstones, mudstones and shales, limestones being almost entirely absent; and the elements of uncertainty within the upper part of the sequence (in relation to the problem of the Ordovician-Silurian boundary) due to the fact that typical Ashgill faunas are not known and that no diagnostic basal Llandovery fossils have been found.

Correlations with Ordovician successions outside the area are considered. Correlations with the British Isles involve considerable difficulties on account of the poorness of Ordovician graptolite faunas in the Massif Armoricain. Shelly faunal relationships between the Massif Armoricain and other areas in the 'Mediterranean Province' (Tethyan region), which have been demonstrated in previous studies, are more or less confirmed. Thus intra-Mediterranean Province correlations seem to involve fewer difficulties, but a progressive approach to these questions remains necessary, beginning with the Iberian Peninsula which presents the nearest relationships with the Armorican area.

RÉSUMÉ. Les récents progrès concernant la connaissance de l'Ordovicien du Massif Armoricain sont présentés. L'attention est attirée sur les regrettables identifications qui furent souvent faites des unités lithologiques et des unités chronostratigraphiques. Une remise en ordre est effectuée dans cette nomenclature. Les résultats sont exprimés sur treize colonnes stratigraphiques et un tableau de corrélations. A l'issue des analyses régionales, une vue synthétique précise le développement de la transgression ordovicienne, souligne le caractère peu profond des dépôts, surtout détritiques, les calcaires étant presque entièrement absents et indique les éléments d'incertitude qui subsistent à la partie supérieure de la séquence (problème de la limite Ordovicien-Silurien), les faunes typiques de l'Ashgill étant inconnues et les fossiles caractéristiques du Llandovery basal n'ayant pas été trouvés.

Les corrélations avec l'Ordovicien des autres régions sont examinées. La pauvreté des faunes de Graptolites rend difficiles les comparaisons avec la Grande-Bretagne. Dans le cadre de la 'province méditerranéenne'; les corrélations sont moins malaisées mais elles nécessitent un effort d'approche progressive en commençant par la péninsule ibérique qui offre les affinités les plus étroites avec le domaine armoricain.

ZUSAMMENFASSUNG. Die Arbeit stellt einen Überblick neuerer Beiträge zur Kenntniss des Ordoviziums des armorikanischen Massifs dar. Die Verfasser machen darauf aufmerksam, dass die unterschiedslose Anwendung lithologischer Einheiten, die man auch als chronostratigraphische Einheiten berücksichtigte, eine grosse

Verwechselung mit sich gebracht hat. Um diese zu vermeiden, schlagen die Verfasser vor, Formationen einzuführen, mit der Absicht örtliche Profile lithostratigraphisch zu übersetzen. Die lithologischen Profile und die darin gesammelten Fossilien sind in der Arbeit kurz beschrieben worden, um eine deutliche Darlegung des Grades der Korrelation darzustellen, der heutzutage zwischen den Schichtenfolgen der verschiedenen Gebiete des armorikanischen Massifs möglich ist. Einige Bemerkungen sind angeführt worden, um die noch bleibenden Zweideutigkeiten zu betonen. Die Ergebnisse drücken sich in dreizehn typischen Profilen und einem Korrelations-Schema aus. Nach den Beschreibungen von Teilregionen ist in der Arbeit eine allgemeine Übersicht der ganzen Region (ausser dem südlichen Gebiet) gegeben worden. Diese Übersicht stellt eine kurze Diskussion der folgenden Probleme. (1) Die Entwicklung der Transgression des Ordoviziums. (2) Die Hauptzüge der Sedimente. Diese sind Seichtwasser-Ursprungs und bestehen aus Sandsteinen, Schluffsteinen, Tonsteinen und Schiefern. Kalksteine sind fast gänzlich abwesend. (3) Die Ursachen der Ungewissenheiten innerhalb des oberen Teiles der Schichtenfolge in Beziehung auf das Problem der Grenze zwischen Ordovizium und Silur.

Danach sind Korrelationen ausserhalb des armorikanischen Massifs berücksichtigt worden. Wegen der Armut der Graptoliten-Fauna des armorikanischen Massifs unterliegen die Korrelationen mit den britischen Inseln grossen Schwierigkeiten. Beziehungen der Schalen-Faunen zwischen dem armorikanischen Massif einerseits, und anderen Gebieten innerhalb der mediterranen Provinz (Tethys-Region) andererseits, die in früheren Arbeiten angedeutet waren, sind in der vorliegenden Arbeit im grossen und ganzen bestätigt worden. Korrelationen innerhalb der mediterranen Provinz scheinen, demzufolge, geringeren Schwierigkeiten zu unterliegen. Diese Fragen sind jedoch nur allmählich und progressiv zu lösen, wobei die Beziehungen mit der Iberischen Halbinsel, die mit dem armorikanischen Massif die grössten Verwandtschaften anweist, im Vordergrund stehen müssen.

THIS review presents the current state of knowledge of the Ordovician over the whole area of the Armorican Massif. The methodology which we have employed to establish a succession of lithological units has been the only one possible, and remains so, in view of the incomplete fauna and the difficulties of correlation with the international stratigraphical scale. However, certain of the terms used ('Schistes intermédiaires', 'Schistes supérieurs') could lead to confusion in the interior of the Massif.

As the succession of Ordovician formations is comparable in the various structural units of the Palaeozoic, names of a purely local character used in the past had only a transitory existence and practice quickly established the use of standard terms, sometimes over the whole of the area. This use of the same terms for Ordovician formations in diverse regions inevitably led to time-correlations, by virtue of a regrettable identification of these lithological divisions as chronostratigraphical units. Despite warnings such as that of Kerforne (1901, pp. 116-25), such a step was encouraged by the inadequacy of palaeontological data. It became necessary to modify and to re-order the stratigraphical nomenclature with a view to avoiding the unfortunate consequences of the excesses of prior schematization (the term 'Schistes à Calymènes' for example had been used for various non-contemporary units). This revision has already been outlined in various recent publications. In conformity with current recommendations, formations are designated by geographical names, and sometimes by lithological terms. Each geographical region in the Massif (text-fig. 1) is discussed separately.

NORMANDY

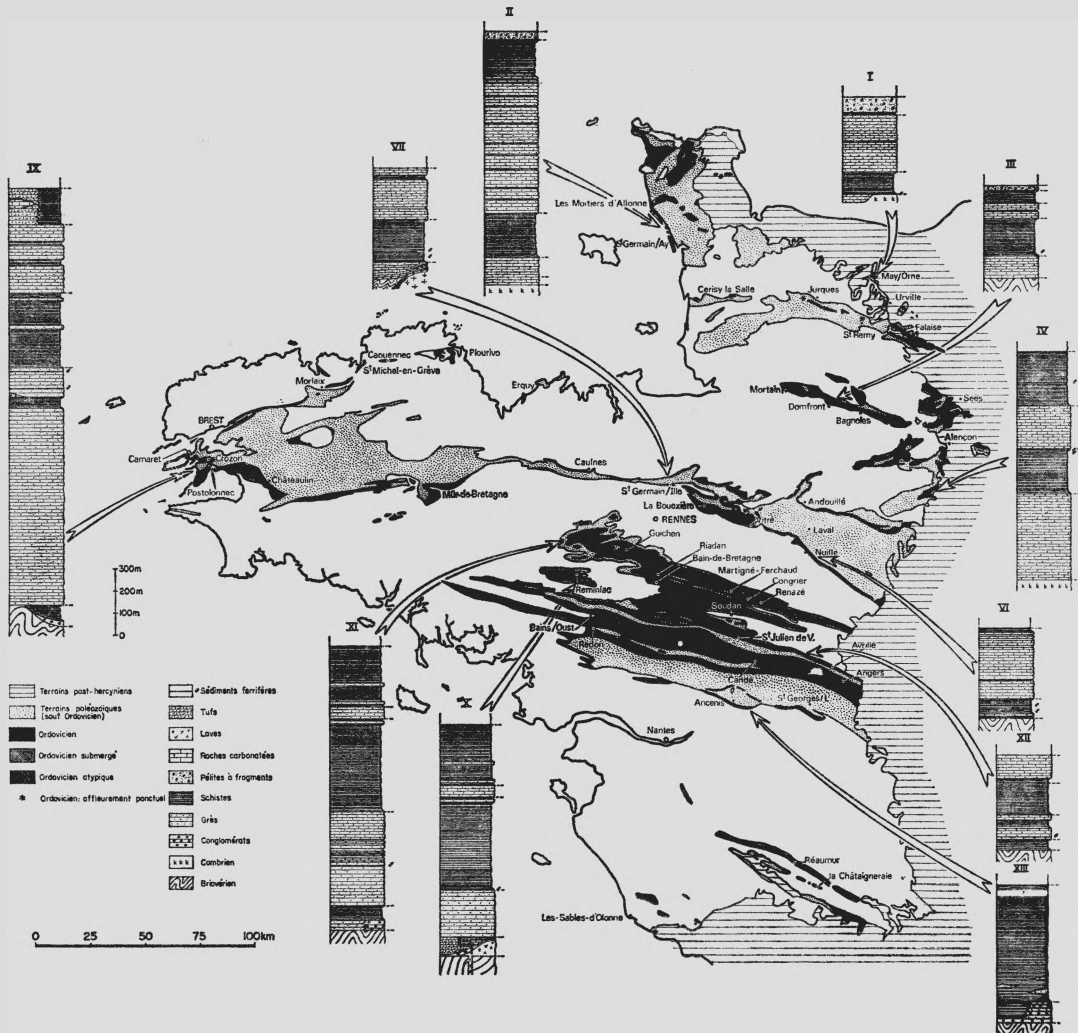
Text-fig. 2, cols. 1-4

1. Central Normandy: the Caen region

Most of the lithological subdivisions subsequently used over the whole of Normandy were defined in this area.

Grès Armoricaïn Formation. This occurs throughout the Urville Syncline, where it succeeds the Cambrian.

In the May Syncline the formation is known only in the east, and in the western part the Urville Formation immediately succeeds the Cambrian 'Grès feldspathiques'. This absence of the Grès Armoricaïn emphasises the progressive nature of the Ordovician transgression. The formation, not very thick here (25 m at Gouvix on the north side of the Urville Syncline), is composed of pale quartzites. As is general in Normandy, palaeontological data relating to this formation are rare. Such data as there are agree with those which, in Brittany, allow the Grès Armoricaïn to be assigned to the Arenig.



TEXT-FIG. 1. Ordovician outcrops of the Armorican Massif. Roman numbers correspond to those of the stratigraphical columns of text-fig. 2.

Urville Formation ('Schistes à Calymènes'): 110 m in the May Syncline, 130 m in the Urville Syncline. Composed of blackish shales, this formation, rich in fossils, has, at or near its base, a band of iron ore (2.50 m at May).

Fauna: The May Syncline: *Didymograptus murchisoni* (Beck), *Neseuretus tristani* (Brongniart), *Crozonaspis mayensis* Clarkson & Henry, *Plaesiacomia? brevicaudata* (Deslongchamps), etc.

Chitinozoan microfauna (Rauscher 1970) rich in *Cyathochitina*.

The Urville Syncline: *Didymograptus bifidus* (Hall), *D. cf. stabilis* Elles & Wood, *D. murchisoni*, *Neseuretus tristani*, *Crozonaspis mayensis*, etc.

The didymograptids indicate that this formation belongs to the Llanvirn.

May Formation. ('Grès de May' s.l.). Separate subdivisions may be found in the two synclines of May and Urville in the thick (260–270 m) essentially sandstone sequence, with the following units from the base upwards:

45 to 55 m of 'ferruginous sandstones', bioturbated, with fine intercalations with *Eohomalonotus vieillardii* (Tromelin), *N. tristani*, cystids and chitinozoans;

90 m of pale sandstones with some bands of dark shale with ripple marks ('Grès de May inférieur' or 'Petit May'). In the May Syncline the fauna comprises *P. ?brevicaudata*, *Crozonaspis incerta* (Deslongchamps), *Eohomalonotus vicaryi* (Salter), *E. serratus* (Tromelin), *E. brongniarti* (Deslongchamps), *Heterorthis* sp. B., chitinozoans;

a very thin band (5–8 m) of shales with *N. tristani*, *Marroliothus cf. bureau* (Oehlert) and *Amplexograptus perexcavatus* Lapworth ('Schistes intermédiaires');

110 to 120 m of thickly bedded sandstone terminating with the 'piebald-beds' spotted red by iron oxides ('Grès de May supérieur' or 'Grand May'). The fauna is poor, with *Eohomalonotus deslongchampsii* (Tromelin) and *Exoconularia pyramidata* (Hoeningh).

'Pélites à fragments' Formation. This begins with 10 to 15 m of unfossiliferous shales ('Schistes supérieurs'), succeeded by strata properly called 'Pélites gréseuses à fragments polyédriques' (60–100 m) whose very remarkable facies of breccia with disseminated clasts is to be found throughout Normandy. Considered originally (Dangeard *et al.* 1962; Doré *et al.* 1963) to be 'the product of sedimentation by submarine mud flows associated with volcanic developments', this formation has more recently been attributed to glacio-marine deposition (Dangeard & Doré 1971; Doré & Le Gall 1973). The poorly preserved fauna (ostracodes and trilobites) recovered from a single exposure (May Syncline) does not allow a decision as to whether this formation should be attributed to the Caradoc or to the Ashgill.

Note. Ordovician formations are also known farther south in the synclinorium of the Bocaine Zone. In the Falaise region, as farther west at Saint Remy or Jurques, there is hardly any precise data.

2. Northern Normandy: Cotentin Peninsula

In the Cotentin Peninsula a remarkable section on the beach at Saint-Germain-sur-Ay allows one to observe a continuous sequence through almost all the Ordovician formations. Other outcrops at various points furnish complementary data on the younger strata in the Ordovician succession.

Grès Armorica Formation. At Saint-Germain-sur-Ay the base of the succession cannot be observed because of a tectonic contact between the Briovérien and the Llanvirn sandstones of the Moitiers d'Allonne Formation. On the other hand, in the

Moitiers d'Allonne Anticline some 20 km to the north, the Grès Armoricain, not very thick (less than 40 m), rests on the Cambrian 'Schistes et grès rouges' with a conglomerate of small quartz pebbles marking the base of the Ordovician transgression.

Moitiers d'Allonne Formation. This group of grey or brown sandstones includes several bands of iron ore with oolites of chlorite, often heavily oxidised at the outcrop. The thickness appears to be about 100 m; only the upper 60 m occurs at Saint-Germain-sur-Ay. The fauna recovered in this area (*Didymograptus murchisoni*) and in the Moitiers d'Allonne Anticline (*D. murchisoni*, *N. cf. tristani*, *Crozonaspis* sp., etc.) makes it possible to date this formation as Llanvirn.

Urville Formation ('Schistes à Calymènes'). This formation (200 m at Saint-Germain-sur-Ay) consists essentially of dark-coloured shales with some bands of dark grey sandstone, which are more common towards the top. At Saint-Germain-sur-Ay, in the middle of the formation, a very rich fossil band has yielded *N. tristani*, *Crozonaspis mayensis*, *Plaesiacomia oehlerti* (Kerforne) and *P. ?brevicaudata*, a fauna identical to that in the Llanvirn shales of the May-sur-Orne Syncline.

Mont de Besneville Formation ('Grès de May' s.l.). This substantial formation (600 m at Saint-Germain-sur-Ay) comprises mainly grey sandstones, the shale intercalations rarely exceeding 1 or 2 m in thickness. Only one fossiliferous layer has been found, at the extreme base; the fauna of trilobites is analogous to that of the lower part of the May Formation ('Petit May') in the Caen region, with *Crozonaspis incerta*, *Eohomalonotus vicaryi*, *E. brongniarti*, *P. ?brevicaudata* and *P. oehlerti*.

Sangsurière Formation (200 m). Alternations of shale and sandstone (40 – 50 m), which link this formation with the underlying Besneville Formation, are succeeded by 150 m of dark micaceous shales. The three fossiliferous horizons observed at Saint-Germain-sur-Ay include a fauna of trilobites, brachiopods, ostracodes and graptolites, including *Onnia grenieri* (Bergeron), *Crozonaspis? dujardini* (Rouault), *Svobodaina armoricana* Mélou, *Ceratopsis* n. sp. aff. *hastata* (Barrande), *Bollia henningsmoeni* Nion and *Orthograptus* sp. Other fossiliferous beds in this same formation at La Sangsurière, Saint-Sauveur le-Vicomte, Saint-Nicolas-de-Pierrepont, etc., have produced a fauna identical to that from Saint-Germain-sur-Ay.

'Pélites à fragments' Formation. The very characteristic facies of this formation (40 – 50 m) are found at Saint-Germain-sur-Ay. No macrofauna has ever been collected, but some acritarchs, which are currently being studied, have been recovered.

Ordovician of the Hague. Knowledge of the Ordovician succession in the north of the Cotentin (Jobourg Syncline and Siouville Syncline) remains very incomplete. Previous research and work in progress are nevertheless revealing close similarities with the Ordovician succession at Saint-Germain-sur-Ay, both as regards the size and succession of formations, and their stratigraphical assignment.

Ordovician of Cerisy-la-Salle. In the eastern section of the Montmartin unit, at Cerisy-la-Salle, the palaeontological data (brachiopods and chitinozoans) is such that a group of sandstones and shales (Doubinger *et al.* 1966) can be attributed to the

Ordovician (Llandeilo or Caradoc). The tectonic style of this region, characterized by the importance of tangential structures, is a major obstacle in explaining the presence and the origin of this isolated Ordovician formation.

3. *Southern Normandy: the Mortain-Domfront-Bagnoles, Sées and Coëvrons synclines*
At Domfront a series of often fossiliferous outcrops allows reconstructions to be made of the whole Ordovician succession and to define stratigraphical limits precisely.

Grès Armoricaïn Formation (100 m). Resting directly on the Briovérien (Mancellia *sensu* Pruvost 1949), this group of pale quartzites includes, towards the top, some rare horizons of black shale. Matte (1906) has reported the existence of '*Asaphus armoricanus*' Tromelin & Lebesconte, '*Lingula lesueuri*' Rouault and '*Dinobolus brimontii*' (Rouault).

Pissot Formation (about 175 m). This very fossiliferous formation ('Schistes à Calymènes'), composed essentially of black shales, includes towards the base some conglomerate beds with phosphatic pebbles and also an iron-bearing horizon; towards the top there is an abundance of silico-argillaceous nodules, often fossiliferous.

The shales and the beds with phosphate pebbles have yielded a varied fauna including trilobites [*Neseuretus* cf. *tristani*, *Ogygiocaris*? sp.], ostracodes [*Aparchites*? sp., *Ctenobolbina hispanica* (Born) and a totally new form related to the genus *Pedomphalella*], some bivalves [*Actinodonta naranjoana* (Verneuil & Barrande), *Cardiolaria beirensis* (Sharpe)], chitinozoans and, principally, graptolites (15 m from the base). The presence of didymograptids, apparently referable to *Didymograptus nicholsoni* Lapworth, *D.* cf. *nitidus* (Hall), *D. ellesae* Ruedemann and *D. v-fractus volucer* (Nicholson), suggests that this level still belongs to the Arenig, or at the outside, to the Arenig-Llanvirn boundary.

A fossiliferous horizon, very rich around the hamlet of Pissot, occurs 15 m from the top of the formation. The fauna includes trilobites [*N. tristani*, *Kloucekia*? *micheli* (Tromelin), *Morgatia hupei* (Nion & Henry), *Panderia*? *beaumonti* (Rouault), *Crozonaspis struvei* Henry and *Plaesiacomia oehlerti*], ostracodes [*Tetradella bussacensis* (Jones), *Eurychilina reticulata* Ulrich, *Kiesowia* sp.A, etc.], brachiopods and bivalves; a single incomplete specimen of a diplograptid is possibly *Glyptograptus vikarbyensis* Jaanusson. The presence in this formation of *Didymograptus bifidus* proves the existence of the Llanvirn (Philippot 1950).

Tertre Chapon Formation ('Grès du Tertre Chapon', or 'Grès de May' s.l.). Despite difficulties in assessment (tectonic disturbances) the thickness of this formation appears to be about 70 m. No macrofauna of any significance has been collected from the dominantly sandstone facies. The alternations of black shales and dark sandstones in the middle of the formation have yielded numerous chitinozoans which are closely comparable to those in the May Formation ('Petit May' and 'Schistes intermédiaires') and in the top of the Andouillé Formation.

Pont-de-Caen Formation ('Schistes du Pont-de-Caen', 'Schistes supérieurs', 'Schistes à Trinucleus'). This formation, in which pale sandstone beds intercalate with dark

shales, is not very thick (about 70 m). Trilobites [*Plaesiacomia* n. sp. aff. *rara* Hawle & Corda, *Crozonaspis?* *dujardini*, *Onnia* sp.], ostracodes [*Ceratopsis* n. sp. aff. *hastata*, *Bollia henningsmoeni*], graptolites [*Diplograptus compactus* Elles & Wood] and chitinozoans were obtained at Domfront and, further east, near Bagnoles and Sées. This fauna has allowed the formation to be dated as Caradoc (Robardet *et al.* 1972).

Pélites à fragments Formation. As observed at Domfront (Maillot 1969) this formation is not very thick (20 m); the usual characteristics of blackish breccia with disseminated clasts are found, together with the same acritarchs as in the Cotentin Peninsula.

Note 1. Between Mortain and Sées, the Domfront section is the only one which offers a sufficiently detailed view of the Ordovician succession. In the west where the Ordovician rests directly on the Briovérien (Mortain), the lithological succession is comparable with that in the east, where it succeeds the Cambrian (Sées), but the palaeontological data are more fragmentary.

Note 2. The Ordovician of the Coëvrons Syncline succeeds a thick Cambrian sequence and is characterized by a much greater thickness than that at Domfront (more than 1000 m). Palaeontological data are scarce. The trilobite fauna discovered (Dangeard 1922) in the Grès Armoricaïn suggests that the top of this formation may belong to the Llanvirn (Henry 1971). The presence of an iron-bearing horizon with *Onnia grenieri*, *Svobodaina armoricana* and *Aegiromena* cf. *descendens* (Havlíček), attributed to the Caradoc, provides a second link. The facies of 'Pélites à fragments' has not been recognized in this syncline.

MENEZ-BELAIR SYNCLINORIUM AND THE NORTHERN LIMB OF THE LAVAL BASIN IN MAYENNE

Text-fig. 2, col. 5

Grès Armoricaïn Formation (from several to about 120 m). In the west this starts generally with a conglomerate of quartz pebbles transgressive on the mudstones and greywackes of the Briovérien and on the Cadomian granites of the Mancellia; to the east it succeeds the dolomitic limestones of the Cambrian. Some psammites or mudstones are developed locally within the formation, without altering its sandstone-quartzite character. The Congrier Member and iron ore have not been observed; only the equivalent of the upper Grès Armoricaïn appears to be represented. Organic activity in the area of sedimentation is shown by *Scolithes*, the tracks of worms, and *Cruziana*. Lingulids, chitinozoans [*Eremochitina baculata brevis* Benoit & Taugourdeau] and acritarchs are rare but allow the formation to be assigned to the Arenig (Deunff & Chauvel 1970).

Andouillé Formation (about 200 m). Succeeding the arenites of the Grès Armoricaïn are siltstones. Less than 50 m from the base chloritic sandstone beds appear, sometimes oolitic; these ferruginous levels rarely exceed 0.75 m in thickness. Microplankton with chitinozoans [*Cyathochitina campanulaeformis* (Eisenack), *C.* cf. *calix* (Eisenack)] and acritarchs [*Cymatiogalea philippoti* Henry], sometimes associated with didymograptids and ostracodes [*Ctenobolbina hispanica*], allow the base of the formation to be attributed to the Llanvirn (Chauvel *et al.* 1970; Paris & Deunff 1970).

The middle part becomes more micaceous; several lenticular sandstone bodies and nodules may be observed. The fauna, rich in individuals but relatively poor in species, is often preserved in nests or in nodules. Trilobites [*Neseuretus tristani*, *Kloucekia* cf. *micheli*, *Placoparia* (*Coplocoparia*) *ournemini* (Rouault), *Crozonaspis struvei*, *Morgatia hupei*] and brachiopods [*Heterorthina* sp. A and sp. B] are dominant in an assemblage including also bivalves [*Redonia deshayesi* Rouault, *Cardiolaria*? *bussacensis* (Sharpe)], gastropods, ostracodes [*Ctenobolbina* sp. A, *Tallinella* sp. A, *Kiesowia* sp. A, *Primitia*? *simplex*, *Tetradella bussacensis*], cystids, and very rare graptolites [*Glyptograptus* sp., *Amplexograptus arctus* Elles & Wood].

At the top of the formation the sediment becomes more argillaceous. Trilobites [*Marrolithus bureau*, *Pl.* (*Coplocoparia*) *borni* Hamman, *N. tristani*], brachiopods [*Aegiromena mariana* Drot], ostracodes [*Ctenobolbina ribeiriana*, *Eurychilina* sp., *Tetradella bussacensis*, *Quadrijugator* sp.] and chitinozoans are found.

Saint-Germain-sur-Ille Formation (about 250 m). This grit unit, in which are intercalated some psammites and pelitic beds, represents the youngest element of the Ordovician. More often than not a unit of blackish micaceous mudstones (5 – 35 m) is developed near the top of the formation. In Mayenne, on the northern limb of the Laval Basin, the grit becomes softer and the psammitic beds dominate. Sedimentary structures (ripple-marks, load-casts, flute-casts) and traces of bioturbation (burrows and tracks) occur on some bedding planes. Unstable conditions of sedimentation are suggested by the existence of channels, of cross-bedding and by sudden influxes of argillaceous sediments rich in organic matter. The formation represents sediments deposited at the boundary between the open sea and supratidal domains.

Very localized fossiliferous horizons sometimes constitute shell banks in the grit beds overlying black shale horizons. The fauna comprises brachiopods [Draboviinae], trilobites [*Calymenella bayani* (Tromelin & Lebesconte) and eohomalonotids], bryozoans and graptolites [*Orthograptus truncatus abbreviatus* Elles & Wood, *O. truncatus truncatus* (Lapworth)]. These diplograptids, from around Saint-Germain-sur-Ille, suggest an upper Caradoc or lower Ashgill age for the middle and upper parts of the formation (Philippot 1950; Skevington & Paris 1975). Near Bouexière, an unusual bivalve fauna has been collected [*Siliquarca typa* Tromelin & Lebesconte, *Lyrodesma lebescontei* Munier-Chalmas]. The sandstone of Saint-Germain has yielded *Onnia* sp. near Vitré. Each faunal assemblage is very localized geographically.

SOUTHERN LIMB OF THE LAVAL BASIN

Text-fig. 2, col. 6

In Mayenne only two formations have been recognized.

Montebert Formation (about 90 m). This forms the first Palaeozoic sediments ('Schistes à Calymènes') transgressive on the Cadomian basement. Here there are no areas of Cambrian strata comparable to those in the north-east of the basin. The formation commences with some 20 m of very micaceous coarse siltstones overlain by quartzose grits and psammites (about 10 m); these beds could be those ascribed to the Grès Armoricaïn by Oehlert (1894). The last 60 m show a homogeneous facies of finer

siltstones, locally including thin sandstone or psammitic beds. The enrichment of the final part by sandstone lenses indicates a transition with the overlying formation. At 10 m above the quartzite and psammitic sandstones, a level of iron ore with chloritic oolites yields acritarchs and chitinozoans [*Cyathochitina campanulaeformis*, *C. cf. calix*] suggesting a Llanvirn age.

Saint-Germain-sur-Ille Formation (about 300 m). This consists essentially of sandstone. Massive beds of quartzose sandstone (1 – 2 m) form the lower 100 m and the sequence is then continued, over about 200 m, by alternations of thin beds of sandstone with chloritic matrix and narrow bands of silt; these latter are more fully developed at the top of the formation. Study of these sandstones suggests more stable conditions for their deposition. The numerous sedimentary structures (oscillation ripples, load-casts), the diverse traces of life, oblique and intersecting laminae, show the influence of active currents and probably indicate that sedimentation took place within a fairly shallow sea. The upper part of the formation has recently yielded a fauna of trilobites (*Onnia* sp.) and molluscs, which indicate a Caradoc age.

THE CHATEAULIN AND TRÉGOR BASIN

Text-fig. 2, cols. 7–9

1. The southern limb of the Chateaulin Basin

The cliff exposures in the Crozon Peninsula furnish the classic localities for this region. A certain confusion reigns, however, over the nomenclature of the Ordovician formations. We cannot follow for example Bishop *et al.* (1969) who employ terms previously used by Barrois but with different meanings. The nomenclature adopted here will be related solely to that of Kerforne (1901).

Pont-Réan Formation (cf. below, p. 372). This essentially comprises the Montfort Member; the extent of the Tréal Member, present only locally, is still poorly known.

The *Montfort Member* here has the same characteristics as in the type-region; however the basal conglomerate is frequently composed of quartz pebbles and the typical red colour often merges into blue because of the considerable development of chloritoid. To the east the horizons of ashy tuffs found in the Pont-Réan Formation along the southern limb of the Chateaulin Basin (Dinidic, le Mendy) can be assigned to the Tréal Member.

The Pont-Réan Formation has a variable thickness along the southern limb of the Chateaulin Basin; reduced towards the east (about 50 m to the south-east of Uzel) it expands westward to reach a thickness of 300 m to the south of Chateaulin. It then thins rapidly and finally disappears to the west of Menez Hom, but re-appears from Beg-Ar-Gwin in Telgruc (about 20 m) as far as Cap de la Chèvre.

Grès Armoricaïn Formation. Here, as in the synclines south of Rennes, the formation possesses three distinct members.

The *lower Grès Armoricaïn* (massive sandstone and quartzite) is very thick in the southern part of the Crozon Peninsula (700 – 900 m); it is reduced to 150 m in the north and to 70 m on the southern limb of the Chateaulin Basin.

The *Gador Member* is composed of sandstone-shale alternations richer in beds of sandstone than those of the Congrier Member (see below). Traces of bioturbation are very abundant and locally there are some iron-bearing beds. Also found are phosphatic pebble conglomerates identical to those in the Congrier Member. Their thickness varies from 50 to 100 m in the Crozon Peninsula and thins to less than 20 m on the southern limb of the Chateaulin Basin.

The *upper Grès Armoricaïn* is characterized by the common presence of psammitic horizons and by thin bedding. Some phosphatic conglomerate horizons are also present and may be accompanied by zircon sandstones and sandstones rich in lingulid shell fragments. A rather thin iron-bearing sediment is developed in certain regions. Locally the upper Grès Armoricaïn commences with a conglomerate of large sandstone pebbles (northern part of the Crozon Peninsula). The fauna is practically confined to lingulids but trace fossils are often abundant. The thickness, greatest at Cap de la Chèvre (150 m), is reduced to 40 or 50 m to the north of the Crozon Peninsula and in the Chateaulin Basin.

Schistes de Postolonnec Formation (about 350 m). *Lower Member*. Lying above the alternation of sandstone and shale at the top of the Grès Armoricaïn, this member begins with about 40 m of dark blue shales, sometimes slaty, in which two decimetre-thick beds with oolites of chlorite and phosphatic nodules contain acritarchs [*Cymatiogalea philippoti*]. The remainder of the member comprises blue shales with abundant siliceous nodules.

In this unit the fauna changes progressively. The lower part (*Schistes de Kerloc'h sensu* Kerforne 1901) contains mainly graptolites [*Didymograptus bifidus*, *D. purchisoni*] accompanied by some trilobites [*Neseuretus tristani*], ostracodes [*Ctenobolbina hispanica*], cystoids [*Phlyctocystis* cf. *granulata* (Chauvel)], and indeterminate bivalves. The middle part (base of the *Schistes de Courijou sensu* Kerforne), which has yielded rare *D. purchisoni*, includes an horizon rich in cystoids [*Calix sedgwicki* Rouault] which accompany trilobites [*N. tristani*, *Eodalanitina macrophthalma* (Brongniart), *Ectillaenus* sp.], ostracodes [*Tetradella bussacensis*, *Pseudulrichia* sp., *Quadrijugator* sp.], bivalves [*Cardiolaria*? *bussacensis*, *Redonia deshayesi*] and brachiopods. The upper beds (top of the *Schistes du Courijou sensu* Kerforne) yield faunas still richer in trilobites [*Neseuretus tristani*, *Colpocoryphe rouaulti* Henry, *Plaesiacomia oehlerti*, *P.*? *brevicaudata*], ostracodes (*Ctenobolbina* sp. A) and bivalves [*Cardiolaria beirensis*, *Ctenodonta ezquerrae* (Sharpe), *Actinodonta naranjoana* (Verneuil & Barrande)]. At the top of this member lenses of calcareous sandstone have recently produced conodonts (Lindström *et al.* 1974).

Kerarvail Member. Although present throughout the Crozon Peninsula this sandstone intercalation is of a variable thickness (about 15 m).

Upper Member. This includes siliceous, silico-pyritic, argillaceous, and sometimes phosphatic concretions. At the top there are intercalations of thin beds of sandstone and some bioturbated horizons. In this member three faunal units can be distinguished.

At the base a substantial unit about 150 m thick (*Schistes de Morgat sensu* Kerforne) contains numerous trilobites; in addition to the species already cited there are *Placoparia* (*Coplapoparia*) *ournemini*, *P. (C.) borni*, *Crozonaspis struvei*, *Morgatia*

hupei, abundant bivalves, ribeirioids, ostracodes [*Ctenobolbina ribeiriana*, *Kiesowia* sp.], and brachiopods [*Heterorthina* sp. B].

A unit of several metres follows, characterized by the presence of *Marrolithus bureau* (Schistes de Kerarmor *sensu* Kerforne).

The final unit, several metres thick (Schistes de Veryac'h *sensu* Babin & Mélou 1972) yields *Colpocoryphe lennieri* (Bergeron), *Dalmanitina* (D.) cf. *socialis* (Barrande), *Myoplusia bilunata perdentata* (Barrande), *Pseudulrichia* sp. A and rare *Ceratopsis* cf. *hastata*; a bed of chloritic oolites and phosphatic balls has yielded the acritarchs *Veryhachium trisulcum* Deunff and *Aremoricanium rigaudae* Deunff.

Grès de Kermeur Formation (about 300 m). This formation is composed of sandstones, often micaceous and interbedded with shales, with various sedimentary structures and trace fossils [*Bifungites*]. The sandstones are not very fossiliferous but at Raguenez two shale masses yield faunas: the 'Schistes de Raguenez' (Kerforne 1901), 50 to 80 m thick, contain calcareous nodules with trilobites [*Onnia seunesi* (Kerforne), *Crozonaspis*? *dujardini*], ostracodes [*Ceratopsis* cf. *hastata*, *Bollia* aff. *henningsmoeni*, *Maratia* sp.], bivalves [*Deceptrix pulchra armoricana* Babin, *Myoplusia bilunata perdentata*, *M. contrastans*? (Barrande), *Concavodonta ponderata*? (Barrande)] and brachiopods [*Svobodaina armoricana*]; higher in the succession the 'Schistes de Kermeur' (Lucas 1939) possess an identical, but rather less abundant fauna.

Rosan Formation (tuffs and limestones of Rosan). This formation is developed in the south-east of the Crozon Peninsula and extends eastwards to south of Chateaulin. Essentially volcanic-sedimentary, the formation includes numerous hyaloclastic breccias (with excellent graded sequences when re-worked), several basic flows showing pillows, and fossiliferous hyaloclastic limestones. The fauna, which is characterized by *Nicolella actoniae* (Sowerby), contains other brachiopods [*Bicuspina spiriferoides* (M'Coy), *Dolerorthis* sp., *Rafinesquina* sp.], trilobites [*Cekovia munieri* (Kerforne)], bryozoans, rugose corals, crinoids, ostracodes and conodonts [*Acodus*? *similaris* Rhodes, *Icriodella superba* Rhodes]. The thin Coat-Garrec bed in Argol, which yields *Leptestiina aonensis* Mélou, *Mespilocystites tregarvanicus* Le Menn, *Ristnacrinus cirrifer* Le Menn and *Heliocrinites* cf. *rouvillei* von Koenen, would seem to fit at the top of the Rosan Formation.

Schistes du Cosquer Formation. For geometrical reasons (identical position above the Grès de Kermeur) it can be assumed that this formation in the northern part of the peninsula is the lateral equivalent of the Rosan Formation. Some 50 m thick, it is composed of black, unfossiliferous shales showing numerous traces of subaqueous instability.

Note. In the eastern part of the Chateaulin Basin, above the Grès Armoricaïn, the other formations cannot be distinguished. There is a substantial mass (about 600 m) of slaty mudstones locally full of chistolite crystals at the contact with the Rostrenen granite. Some palaeontological markers led Barrois to distinguish the 'Schistes des Salles-de-Rohan' for the lower part of this sequence (based on the presence of *Neseuretus tristani*) and the 'Schistes de Ste.-Brigitte' for the upper part (based on the presence of *Marrolithus* cf. *bureau*). The sequence is completed by some 50 m of greenish shales with white sandstone lenses.

2. Northern limb of the Chateaulin and Trégor Basin

The Ordovician formations are difficult to identify on the northern limb of the synclinorium, as they are less well developed and are affected by an important tectonic break. Along the Elorn, Chauris & Hallegouët (1973) distinguish three formations: the Grès Armoricaïn represented by the 'Quartzites de la Roche Maurice' which do not exceed 80 m, the 'Schistes de Kerautret' of unknown thickness (some tens of metres) and the 'Grès et schistes de Kerfaven' which are thought to exceed 100 m. This group has not yet yielded any fauna. The Grès Armoricaïn Formation can be traced towards the south-east in the Monts d'Arrée, and towards the east in Trégor (Barrois 1886; Chauris 1971) as the sandstones and quartzites of Toulgoat, Plouézoch, St.-Michel-en-Grève, Caouennec, and perhaps, Plourivo.

Note. The Ordovician age of the sequence at Erquy (Saint-Brieuc Bay) raises some important and still unresolved problems. Previously considered as the equivalent of the amphibolitic formations at the base of the Briovérien in Saint-Brieuc Bay (Barrois 1895, 1934; Barrois *et al.* 1938, 1941), the spilitic sequence at Erquy was chosen as the 'type' for the Lower Briovérien. The radiometric age (Vidal *et al.* 1971) of the volcanic part of this sequence (466 ± 10 m.y.) has been confirmed by the discovery, in the interbedded layers between the spilitic flows, of micro-organisms which may be attributable to the Lower Ordovician (Deunff *et al.* 1973). The sedimentary, volcanic and structural characteristics of this sequence are quite unexpected in the Grès Armoricaïn, where study of the Ordovician succession has never revealed similar phenomena.

SYNCLINES SOUTH OF RENNES

Text-fig. 2, cols. 10, 11

It is in the synclines to the south of Rennes that type localities have been selected for the formations which form the base of the Palaeozoic of Brittany.

The *Marsac Formation* is well developed on the northern limb and at the eastern extremity of the Réminiac Syncline where it rests on the pre-Palaeozoic basement; it is composed essentially of volcanic deposits (aerial flows and pyroclastic products). The lavas, generally microlithic, have a composition varying from soda keratophyre at one extreme to dacite at the other. The associated products of explosion are breccias and tuffites.

Pont-Réan Formation. This comprises several members, certain of which have only a restricted extent. To date this formation has not yielded any organic remains.

The *Montfort Member* ('Schistes rouges', 'Dalles pourprées') is the principal component of the Pont-Réan Formation, and it may represent its entirety. The thickness of the member is very variable (0 – 350 m). This reddish coloured sandstone-shale (quartz-wacke) unit has a basal conglomerate of sandstone pebbles in a sandy matrix. In the Réminiac region it also contains bands of volcanic origin.

The *Courouet Member*, present only to the north of a line from Bain-de-Bretagne to Saint-Aignan-sur-Roë, is composed mainly of white to greenish sandstones, locally conglomeratic. It is a lateral equivalent of the basal beds of the Montfort Member.

Its maximum thickness is about 50 m. In the Réminiac region it is represented by a facies of acid volcanics.

The *Tréal Member* comprises an assemblage of fine volcanic tuffs and breccias, rich in acid volcanics. It is well developed on the southern limb of the Réminiac Syncline (50 m maximum) and it passes laterally into the Montfort Member. It is also present on the southern limb of the Guignen Syncline. The volcanic phenomena reflect a phase of activity which was essentially explosive. This phase would appear to be later than that of the extrusives of the Marsac Formation, and would thus seem to demonstrate a progressive change in the extrusions from sodic to more acid.

Grès Armoricaïn Formation. The transition between the Pont-Réan Formation and the Grès Armoricaïn is gradual. Where the Pont-Réan Formation is absent, the Grès Armoricaïn rests directly on basement. Typically the formation comprises three units.

The *lower Grès Armoricaïn* is a thickly bedded quartzitic sandstone which includes four layers of iron ore. Its average thickness is about 250 m but locally it may attain 450 m (Maleroche to the south of Rennes).

The *Congrier Member* ('Schistes intermédiaires' *sensu* Kerforne 1901) is composed of alternations of shale and sandstone (110 – 120 m) with numerous calcareous beds making up the lowest 10 to 15 m.

The *upper Grès Armoricaïn* consists of a succession of beds of quartzite, sandstone, psammite and shale (about 120 m). The fauna consists of rare bivalves, including *Nuculites? acuminatus* Barrois, *Synech antiquus* Barrande, *Actinodonta carinata* Barrois, *A. obliqua* Barrois and *Lyrodesma armoricana* Tromelin & Lebesconte.

These three members are present in all the synclines to the south of Rennes, except for that of Réminiac where the Grès Armoricaïn comprises a single mass of white sandstone between 200 and 250 m thick.

Traveusot Formation (300 – 400 m). Most frequently referred to by the term 'Schistes à Calymènes' or 'lower slaty beds', this formation of black shales, rich in siliceous nodules, is fossiliferous. In the past numerous subdivisions have been made, generally based on the presence of one or several fossils considered as 'characteristic' (de Tromelin & Lebesconte 1877). These subdivisions, created on the basis of imprecise determinations, should be abandoned. It has been proposed to designate the 'Schistes à Calymènes' in all the synclines south of Rennes as the Traveusot Formation (Henry & Clarkson 1975). At locality '85' in Laillé, the base of the formation comprises 50 to 60 m of black shales containing graptolites [*Didymograptus* cf. *bifidus*], trilobites [*Trinodus* sp., *Pseudosphaerexochus* (*Pateraspis*) sp., *P. (Placoparia) cambriensis* Hicks] and some ostracodes [*Ctenobolbina hispanica*, *Parenthatia?* sp., *Ulrichia* sp.]. These fine beds are succeeded by rather coarser, micaceous bands with siliceous nodules. It is not possible to give a precise thickness for these nodule beds which are visible in the railway cutting on the Rennes-Redon line ('Laillé halt') and also in the fields bordering Traveusot Farm. The siliceous nodules yield a rich fauna of trilobites, including *P. (Coplacoparia) tournemini*, *Colpocoryphe rouaulti*, *Z. (Zeliszella) lapeyrei* (Bureau), *Guichenia dufouri* (Tromelin & Lebesconte), *Kloucekia? micheli* (Tromelin), *E. (Eccoptochile) mariana* (Verneuil & Barrande), *Prionocheilus* sp., *Dionide* sp., *Eoharpes guichenensis* Henry & Philippot and *Panderia? beaumonti*. To these must be added ostracodes, represented by the genera *Tallinnella* (abundant), *Lomatolbolbina*,

Kiesowia, *Aechmina*, *Ulrichia* and *Ctenobolbina*, and brachiopods [*Aegiromena mariana*], bivalves [*Praeleda costae* (Sharpe)], echinoderms [*Calix* sp., *Mitrocystella incipiens miloni* Chauvel] and some rare *Glyptograptus* cf. *teretiusculus* (Hisinger).

Chatellier Formation (maximum 70 m). The most common facies is represented by green chloritic sandstone, locally containing white quartzitic bands. This formation, non-fossiliferous(?) but remarkably uniform in all the synclines south of Rennes, provides an excellent mappable marker band.

Riadan Formation (250 – 300 m). This is well known in the Renazé sector, because of the exploitation of its slate vein. From the base to the top may be distinguished:

- 100 to 150 m of coarse micaceous shales with numerous green sandstone nodules;
- 25 to 30 m of fine cleaved mudstones, which constitute the slate vein;
- 80 to 120 m of coarse micaceous schists which may contain green sandstone nodules and some rather finer-grained bands.

The fauna, collected principally from the slate vein (Riadan), includes rare echinoderms [*Mitrocystis riadanensis* Chauvel], some ostracodes [*Ceratopsis* n. sp. aff. *hastata*] and poorly preserved trilobites [*Dalmanitina* (*Dalmanitina*) sp., *Colpocoryphe lennieri*, *Crozonaspis*? *dujardini*, *Prionocheilus verneuli* Rouault, *Selenopeltis* sp.]. The deposits which overlie the Riadan Formation begin with a white quartzitic sandstone band from 20 to 25 m thick ('basal sandstone'). In the Réminiac region it has yielded a Llandovery graptolite fauna.

THE REDON-ANGERS SYNCLINORIAL AREA

Text-fig. 2, col. 12

1. Northern limb of the 'Saint-Julien-de-Vouvantes-Angers' synclinorium

The Ordovician sequence here corresponds closely to that of the synclines to the south of Rennes, but is reduced in thickness.

Margat Formation (about 100 m). Violet or greenish schists with intercalations of conglomerate and rare lingulaceans, appear to take the place of the Pont-Réan Formation. They are absent to the east, beyond the Loire.

The Grès Armoricaïn Formation shows its usual tripartite nature: lower Grès Armoricaïn with iron ore and *Cruziana* (50 m); Schistes du Pavillon ('Schistes intermédiaires', 'Congrier Member') (30 m) and upper Grès Armoricaïn (15–20 m) with rare fossils [*Ogyginus armoricanus* (Tromelin & Lebesconte), *Hippomya*? *salteri* Barrois, *Synek antiquus*, *Actinodonta obliqua*, *Lyrodesma armoricana*].

Schistes d'Angers Formation. We propose to retain this term for the blue-black shales, about 150 m thick, which directly overlie the Grès Armoricaïn. A lower unit with *Didymograptus murchisoni* is succeeded by shales with argillo-siliceous nodules, with very abundant *Neseuretus tristani*, *Colpocoryphe rouaulti*, *C. salteri* (Rouault) and ostracodes [*Tallinnella* sp.].

Avrillé Group (400 m). Sandstone nodules at the base of this predominantly shaly group have yielded *Onnia grenieri*, *D. (Dalmanitina) cf. socialis* and *Kloucekia aff. philippsii* (Barrande). Higher up, the Ordovician strata have yet to be determined palaeontologically; but large fossiliferous sandstone nodules, so-called 'spheroids', and intercalations of black shales with monograptids provide evidence of the presence of the Silurian in this group.

2. *Southern limb of the 'Saint-Julien-de-Vouvantes-Angers' synclinorium and the 'Landes-de-Lanvaux-Les-Ponts-de-Cé' anticlinal area*

Shales and arkoses of the Bains Group. Beneath the 'Schistes d'Angers' (cf. below) are found thick, detrital, unfossiliferous formations which, following Barrois & Bochet (1889), have been referred to as the 'Schistes et arkoses de Bains'. Over a distance of more than 200 km this complex forms a narrow anticlinorial zone whose axis is marked, in discontinuous fashion, by a long extension of the Landes de Lanvaux Granite (to the west) and by the 'window' of the Saint-Clément-de-la-Place Orthogneiss (to the east). The granite and the orthogneiss are usually interpreted as forming the Precambrian basement to the shales and arkoses (Faure-Muret 1945; Chauris & Lucas 1964). However, the contacts between the two units are everywhere faulted and this hypothesis cannot be verified, and neither can the precise thickness of the 'Shales and arkoses' be evaluated. It would thus be premature to give a detailed description of this complex, although the following points are worthy of mention at present.

In the Bains-sur-Oust region, where it was defined, this group comprises grey to rose-coloured shales, ochre sandstones with elongated quartz grains, and fine to coarse arkoses. Lenses of conglomerate ('Poudingue du Dréneux') are common at various levels. At the top, alternations of shale and arkoses are separated from the 'Schistes d'Angers' by several metres of blue quartzites.

In the Angers region, the core of the anticline is occupied by shaly formations rhythmically alternating with sandstone-greywackes containing several beds of feldspathic microconglomerate. Higher in the sequence the coarse detrital facies predominate over the shales, constituting thick sequences of arkosic sandstones, micaceous sandstones, and often feldspathic microconglomerates with small quartz pebbles. At the contact between the 'Shales and arkoses' and the 'Schistes d'Angers' there are alternations of thin sandstone-shale units with iron ore; these apparently take the place of what, on the northern limb, belongs to the lower Grès Armoricaïn.

The problem of the age of the 'Schistes et arkoses de Bains' is a difficult one. They apparently lie conformably beneath shales whose base may reasonably be attributed to the Llanvirn, and this complex is usually considered to be laterally equivalent to the succession made up elsewhere in Brittany by the Pont-Réan Formation and the Grès Armoricaïn. In the absence of really new and indisputable information, it is prudent to maintain that interpretation. It should be remembered, however, that in many of their outcrops the most shaly sequences are distinctly similar to the Briovérien seen in the northern part of the Angers Synclinorium. Besides this, certain of the shale outcrops in the core of the anticline reveal the presence of small recumbent folds, unusual in the Palaeozoic cover of the Armorican Massif. It is therefore understandable that the hypothesis of a Briovérien age for part at least

of the complex studied here, should remain for the present. Only the alternations of shale-sandstone with iron ore, which provide evidence of continuity of sedimentation with the 'Schistes d'Angers', can be assigned with near certainty to the Ordovician. At their base, and indeed much lower in the succession, and in particular below the thick arkosic formations of the Angers region, one cannot rule out the possibility of a stratigraphical break, as yet undetected. It should be noted in this connection that the existence, in the immediate vicinity of Angers, of a biotite-grade metamorphism within the shales and arkoses, does not bring any new element to the problem. Indeed, under the 'Schistes d'Angers', this metamorphism affects the shale-sandstone alternations with iron ore; moreover it results in the appearance there of stilpnomelane and amphiboles.

Note. In two localities more than 20 km apart—the Pont de la Pile (2.5 km SW of Saint-Julien-de-Vouvantes) and the former iron mines of La Boserie (4 km NE of Candé)—some micaceous sandstones in thin sheets, with impressions of *Didymograptus*, have been assigned to the Arenig (Philippot 1950). From La Pile that author described *D. falco* and cited *D. cf. hirundo* Salter. The intermittent nature of these outcrops does not allow the unequivocal assignment of the 'Psammities de la Pile and of la Boserie' to the 'Shales and arkoses of Bains' complex.

'Schistes d'Angers'. In the absence of fossils collected *in situ* in the blue-black, phyllitic shales which overlie the 'Shales and arkoses of Bains', the stratigraphical position of this unit remains uncertain (Llanvirn to Caradoc?). For this reason, the slates of Trélazé and of La Pouèze have been examined in old collections and the following fossils identified: *Placoparia* (*Coplocoparia*) cf. *tournemini*, Z. (*Zeliszella*) *lapeyrei*, *E. (Eccoptochile)* cf. *mariana*, *Dionide* sp., *Uralichas* cf. *heberti* (Rouault), *Ectillaenus* sp.

3. Saint-Georges-sur-Loire Synclinorium

Many uncertainties exist as to the stratigraphical and structural interpretation of the almost unfossiliferous, very uniform shale-sandstone successions which occupy this vast synclinorium to the south of the 'Landes-de-Lanvaux-Les-Ponts-de-Cé' axis.

Eastern area. Two mappable units whose correlation is far from clear have been distinguished (1:50,000 Angers map sheet).

To the north, the 'Schistes de Bouchemaine et d'Erigné' seem to represent the upper part of the Ordovician. However, the recent discovery of monograptid fragments in the rare thin intercalations of black shale and siliceous shale shows that the Silurian is represented here. On the other hand, the presence of trace fossils belonging to the *Cruziana* group prevent complete abandonment of the hypothesis that the lower Ordovician may reappear in folds under facies which are unknown farther north. A search for microplankton has proved negative.

To the south, the *Saint-Georges-sur-Loire Group*—shale-sandstone sequences and volcanics (spilites, rhyolites, tuffs) rich in intercalations of siliceous shales with *Monograptus lobiferus* (M'Coy)—is evidently Silurian in part, but that does not preclude the possibility that the upper part of the Ordovician is also present here.

Western area. The absence of any fauna makes it difficult to identify the Ordovician. The Palaeozoic starts with 150 m of rose-coloured quartzites with iron ore, which one

can reasonably attribute to the Grès Armorica Formation. Above come phyllitic black shales, very similar to the 'Schistes d'Angers'. The Ordovician then continues with formations very similar to those in the eastern part of the synclinorium.

THE ANCENIS SYNCLINE

Text-fig. 2, col. 13

1. North of the Loire

On both limbs of the fold the 'Shales and quartzites of Pierremelière' contain small sandstone nodules with *Colpocoryphe inopinata* (Novak), *Pricyclopyge binodosa* (Salter), *Ormathops* cf. *atavus* (Barrande) and *Lagynocystis pyramidalis* (Barrande). This fauna gives a Llanvirn age to at least the lower part of the schists and quartzites, the contact of which with the Briovérian metamorphics is everywhere faulted. No younger fossils have yet been observed in this area within the pre-Frasnian Palaeozoic.

2. South of the Loire

The *Moulin de Chateaupanne Formation* (about 100 m) comprises conglomerates and sandy pelites, often red or brownish in colour. It lies unconformably on the epimetamorphic Briovérian of the Mauges. In its upper part it includes the 'Schistes de Piffaumont' which are pale-coloured and finely micaceous. Very small inarticulate brachiopods (Acrotretidae), at present under study, and large conodonts can be collected. M. Lindström has identified species of *Panderodus* and *Drepanoistodus*, allowing the Palaeozoic transgression to be dated here as Arenig.

The *Schistes du Fresne Formation* ('Shales with Fucoids'), composed of somewhat sandy and micaceous shales, with quartzitic intercalations, succeeds the preceding formation but is generally faulted against the Briovérian. These facies strongly resemble those of the 'Shales and quartzites of Pierremelière'. With the exception of enigmatic traces (*Chondrites*?) these beds have not as yet yielded anything other than small gastropods, an 'orthoceratid' and two trinucleid fragments. The relationship between this unit and other darker and finely micaceous pelites, seen a short distance away in the quarry of Chateaupanne, are not known. Although situated only one metre below the Chalonnes Limestone (latest Emsian) these pelites, which have yielded several fragments of *Dicellograptus* associated with *Sporangites penau* Carpentier, still belong to the Ordovician.

VENDÉE

To the south of the Armorican Massif, the Ordovician is present in narrow and discontinuous synclines. Mathieu (1936) compared the 'White Quartzite of the Chataigneraie' (50 – 100 m thick) with the Grès Armorica. Bivalves were subsequently found in blue-black shales of Réaumur (Mathieu 1938), of Chaise-le-Vicomte (Brillianceau 1962) and of the Bouchetière (Brillianceau & Mathieu 1965). The presence of *Cardiolaria beirensis*, *Ctenodonta ribeiroi* (Sharpe) and *Praealeda costae* allows

assignment of the shales of Réaumur to the Schistes de Postolonnec Formation. Mathieu later suggested (1972) that the porphyrites of Vendée could be of upper Ordovician age. The presence of the Ordovician is thus firmly established as far as the southernmost outcrops of the Armorican Massif.

EVOLUTION OF THE SEDIMENTATION AND THE FAUNA

Palaeozoic transgression and lower limit of the Ordovician System

Throughout the Armorican Massif the Lower Palaeozoic sediments are transgressive and discordant on the Precambrian basement. As far as the Ordovician is concerned, its lower limit can be defined with varying degrees of confidence, depending on the area in question.

In the east and north-east this lower limit poses little problem; the first Ordovician sediments (Arenig or Llanvirn) overlie either the Cambrian, in which case a discontinuity (emergence) separates them, or (Mancellia) the granites or Briovérien formations of the Cadomian basement.

In those regions (Chateaulin Basin, synclines south of Rennes, northern limb of the Saint-Julien-de-Vouvantes–Angers Synclinorium) where the Grès Armoricaïn succeeds earlier formations of unknown age (Marsac Formation, Pont-Réan Formation) without a break the problem of the lower limit of the System is still unresolved.

Finally, in the southern regions (to the south of the Landes-de-Lanvaux–Ponts-de-Cé anticlinal area) the Ordovician succession, without clearly distinct formations, is atypical. These very special conditions at present prevent any clear definition of the nature of the transgression or of Ordovician sedimentation: these southern regions will not be considered therefore in the following synopsis.

The absence of synchronism in the development of the transgression may be noted, as shown especially by the partial absence (Menez–Belair Synclinorium and northern limb of the Laval Basin), or total absence (western part of the May-sur-Orne Syncline, southern limb of the Laval Basin?) of the Grès Armoricaïn and, probably, by the considerable regional differences in the thickness of this formation (from several to more than 1000 m). The transgression was very extensive after the Arenig, reaching its maximum with the shaly deposits of the Llanvirn. Its development was accompanied by deposition of iron-bearing sediments varying in age according to region (Arenig to Llanvirn).

The features of the Ordovician transgression indicate a sustained trend of subsidence, in contrast with previous periods in which differential instability of the Cadomian basement apparently took place during: (a) Cambrian times, where in the east and north-east of the Armorican Massif, regression and successive and localized emergences took place, sometimes accompanied by acid volcanism (locally, however, an important subsidence affected certain Cambrian beds, e.g. at Charnie and Coëvrons); and (b) in an ill-defined Palaeozoic epoch, preceding or contemporary with the first known Palaeozoic deposits, when in certain regions of Brittany (Chateaulin Basin, synclines south of Rennes) there was volcanic activity (Marsac Formation, Pont-Réan Formation).

Sedimentation and faunas

In all the regions where it is well known the Ordovician succession is composed of epicontinental deposits, as indicated notably by the lithofacies (iron ore, horizons of phosphatic pebbles, conglomerate bands, etc.), by sedimentary structures (cross bedding, channels, ripple-marks, load-casts, flute-casts, etc.) and numerous traces of organic activity (tracks, burrows, etc.).

In the lithological succession, which is essentially detrital (alternation of sandstones and shales), with limestone facies practically absent, the relatively fine character of the sediments does not indicate differences in depth of deposition but only variations in the nature of the material supplied.

On the other hand, the epicontinental character of the deposits leaves open the possibility of lacunae in sedimentation which have not yet been detected, but which cannot be excluded *a priori* because of the very imperfect state of present palaeontological knowledge. In spite of a certain uniformity in the lower part of the succession (Grès Armoricaïn and succeeding shale formations), the variability of the facies makes all correlation between lithological units somewhat illusory.

Various pieces of evidence support the view that Ordovician marine sedimentation was influenced by special local or regional factors. The evidence includes considerable thickness differences for the complete succession, or of coeval sediments; the generally very elongate shape of existing synclines (zones predetermined at the time of sedimentation?); the presence in certain synclines of sedimentary channels; and the existence of different faunal domains and faunas of endemic character.

Thus it is possible to envisage that, during the Ordovician, marine sedimentation was influenced by the existence in the underlying strata of structural features (division of the basement into blocks with different behaviour). The distribution of the fauna, especially the trilobites, appears to reflect a certain degree of provincialism with three palaeobiogeographical domains being recognizable, corresponding respectively to the Cotentin, to the median synclinorium, and to the synclines south of Rennes. Certain exchanges do occur from time to time between these domains, but this does not invalidate the characteristic nature of these associations. For the trilobites, very marked Bohemian influences are observed only in the southern part of the Massif, beyond the anticlinorial axis of Lanvaux. On this north-south gradient of geographical distribution (Clarkson & Henry 1969) there would appear to be superimposed an east-west gradient (Babin & Mélou 1972), manifested in particular in the benthonic fauna by the progressively more important arrivals of eastern species during the course of the Ordovician.

Upper limit of the System

The variability of the facies is particularly marked in the upper part of the succession, where many problems remain unresolved. For example, the age of the 'Pelites with fragments' remains imprecise, and this glacio-marine formation has not as yet been recognized other than in the north-east of the Armorican Massif (Normandy). Also, at the western extremity of the median synclinorium, the volcanic-sedimentary tuffs and limestones of Rosan provide evidence of local volcanic activity, but the genetic relations with its lateral equivalent (Schistes du Cosquer) remain poorly understood.

Related to these problems, and of general sedimentological and palaeogeographical interest, is the problem of the upper limit of the Ordovician. Firstly, the supposed existence of Ashgill horizons in certain successions (top of the Saint-Germain-sur-Ille Formation, top of the Rosan Formation, and 'Pelites with fragments' of Normandy) cannot be sustained with certainty. And secondly, it has never been possible to obtain graptolite evidence from the base of the Silurian. If one excludes the locality at Domfront, where *Climacograptus normalis* and *Orthograptus truncatus abbreviatus* (top Ashgill or base of Llandovery?) have been found in the sandstones ('Grès culminant') which overlie the 'Pelites with fragments', then everywhere else in the Armorican Massif the first Silurian horizons known belong to the middle Llandovery.

CORRELATIONS

Within the Armorican Massif

The faunas of the Armorican Ordovician show a certain unity and their succession is comparable in the various regions studied. However, many of the stratigraphical correlations remain imprecise. Indeed, the interval separating known fossiliferous horizons (see text-fig. 2) is sufficiently great to allow uncertainties to remain about the age of some of the formations.

Since the faunas of trilobites, ostracodes, brachiopods and bivalves are relatively poor, and since the same associations appear to persist through a long interval, more attention must now be given to the development of research on the microplankton (chitinozoans and acritarchs), the conodonts and the graptolites.

With the Ordovician of the British Isles and other regions

Comparisons between the Armorican Massif and the British Isles, and thus correlations with the stratotypes of the Ordovician, raise some rather subtle problems. The benthonic faunas of the Armorican Ordovician (brachiopods, bivalves etc.) are of Mediterranean character and are essentially distinct from those of the British area; they contain hardly any elements which allow direct correlations to be established between the Armorican Massif and Great Britain. Such correlations have to be attempted using the graptolite faunas, which remain the most useful (Williams *et al.* 1972, p. 7) for establishing the contemporaneity of Ordovician formations. With the exception of the Llanvirn didymograptids, graptolites are rare in the Armorican Ordovician. Not only are there few graptolitic horizons known, but these in general include only a small number of species, often monotypic, with the material sometimes being limited to a few incomplete specimens. Correlations with the standard British graptolite zones are thus rarely possible and, more often than not, are only approximate. Our correlation table is therefore intended (text-fig. 3) mainly to set out the chronological position of the Armorican formations described above; the standard scale is added only to provide a working hypothesis, but the post-Llanvirn successions cannot be referred to it with any precision.

TEXT-FIG. 3. Attempted correlation of principal Ordovician formations in the Armorican Massif. For each formation the age envisaged is represented by a vertical stroke, the margin of uncertainty being shown by dashes. Known or very probable lacunae are shown by cross-hatching.

ÉCHELLE STANDARD DE GRANDE - BRETAGNE	SYNCLINAUX DE NORMANDIE			SYNCLINORIUM MEDIAN			SYNCLINAUX DU SUD DE RENNES	AIRE SYNCLINORIALE REDON-ANGERS			SYNCLINAL D'ANCENIS	SYNCLINAUX DE VENDEE	ÉCHELLE DE BOHÈME (Havlíček & Marek, 1973)
	Région de Caen	Cotentin	Domfront	Flanc nord du Bassin de Laval et Ménéz-Belair	Flanc sud du Bassin de Laval	Presqu'île de Crozon		Flanc nord du Synclinal d'Angers	Flanc nord de l'aire anticlinale Lanvaux-P ^{le} de Cé	Synclinarium de St Georges/Loire			
LLANDOVERY				?									
ASHGILL	Pelites à fragments	Pelites à fragments	Pelites à fragments	?				Groupe	Groupe	Groupe de St Georges- sur-Loire			KOSOV
CARADOC		Formation de la Sangurrière	Formation du Pont- de-Caen Formation du Terre-Chapon	Formation de St Germain/Ilie	Formation de St Germain /Ilie	Formation du Cosquer Formation de Kermeur	Formation de Ridon Formation du Chateilier	d'Aurillé	d'Aurillé	Schistes de Bouchemaîne et d'Erigné	Formation des Schistes du Fresne		BEROUN
LLANDEILO	de Moy	Formation du Mont de Besneville	Formation	Formation	Formation	de	de	Formation des Schistes	"Schistes	"Schistes			DOBROTIČ
LLANVIRN	Formation d'Urville	Formation d'Urville	Pisset	d'Andouillé	de Montebert	Postolonnec	Traveusot	d'Angers	d'Angers	d'Angers		Schistes de Réaumur	LLANVIRN
ARENIG	Grès Armorican	Formation du Grès Armorican	Formation du Grès Armorican	Formation du Grès Armorican		Formation du Grès Armorican	Formation du Grès Armorican	Formation du Grès Armorican	Groupe des Schistes et arkoses de Bains	Groupe des Schistes et arkoses de Bains	Formation du Moulin de Châteaupanne	Quartzite de la Châtagnerie	ARENIG
TREMADOC						Formation de Pont- Réan	Formation de P ^{le} Réan	Formation du Margot					TREMADOC

Comparisons with other areas in the 'Mediterranean Province' ('Tethyan Region') raise rather fewer difficulties. Certain faunal affinities exist between the Armorican Massif, Morocco and Bohemia, although these affinities are generally most apparent at the generic level. There are very close similarities with the faunas of the Iberian Peninsula and, more especially, with the Lusitanian Province. In a general palaeogeographical framework, it seems that the Armorican-Lusitanian faunas, less varied than those of Bohemia, rich in endemic forms but devoid of coelenterates up to the Caradoc, could be considered indicative of relatively cold water conditions (which is also consistent with the scarcity of limestones). The exotic faunas arriving in the middle or upper Caradoc probably originated in various warmer provinces (Bohemia, but also Great Britain for certain forms such as *Nicolella actoniae*). In fact, the identity of the faunas, and of the Armorican and Lusitanian micro-organisms, appears to us largely to weaken certain palaeogeographical reconstructions, such as that of Smith *et al.* (1973) in which the Armorican and Iberian areas are totally separated and situated at quite different latitudes. Hypotheses which allow for the juxtaposition of the Iberian and Armorican blocks in the Palaeozoic are much more consistent with the evidence at our disposal. A scheme involving an Iberian-Armorican arc relies on structural arguments (Cogné 1971; Bard *et al.* 1972) but it is appropriate to stress once more how remarkably identical are the sediments, the faunas, and their geographical distribution in the Ordovician for the Armorican-Lusitanian Province. Moreover, several authors have, more recently, stressed (Bishop *et al.* 1969) or refined (Henry & Thadeu 1971) the similarities which have long been reported, but in which interest should now be revived in the light of plate tectonic models.

Finally, it would seem that to establish precise correlations, the most effective method would be to proceed by successive approximations commencing with regions, such as the Iberian Peninsula, which appear to present the closest similarities to the Armorican Massif. One would hope thus to arrive at correlations between the Armorican Ordovician and the British stratotypes, utilizing for example the Bohemian succession which has, at least in part (Havlíček & Vaněk 1966; Havlíček & Marek 1973), been correlated with the standard scale of the Ordovician.

The Ardennes and Montagne Noire regions, although relatively close geographically, allow very little precise correlation with the Armorican Massif. In the Ardennes (e.g. Michot 1954) where there is a terrigenous Ordovician sequence, dislocated by Hercynian tectonism, the palaeontological data are in need of careful re-examination. In the Montagne Noire (e.g. Geze 1949; Dean 1967), whilst the base of the Ordovician, which is restricted to the lower and middle Arenig, has been the subject of recent research (Dean 1966), the upper part (Caradoc and perhaps Ashgill) which follows an important lacuna (Taconic episode), would also merit being re-studied.

The conclusions and opinions outlined above thus call for the development of research both on graptolites (work currently being undertaken in collaboration with D. Skevington), and equally on other groups which will provide data for long-distance correlations. Conodonts (work in progress with M. Lindström) and microplankton (acritarchs and chitinozoans, currently being studied by J. Deunff and F. Paris) are known to be of stratigraphical value and some samples are already proving to be of interest (Henry & Thadeu 1971).

It would be illusory, therefore, to consider this review as final. We hope that by putting forward clearly not only the facts already known, but also the problems which remain to be resolved, it will help towards a better understanding of the Armorican Ordovician and will furnish a basis for later correlations.

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DISCUSSION

M. Romano. I welcome the work by Professor Babin and his colleagues in establishing a formal stratigraphical nomenclature for the Ordovician in the Armorican Massif. In north Portugal we also have found it necessary to erect formational names to replace the better known but less stringently defined terms such as 'Quartzites à Bilobites' and 'Schistes à Didymograptus'.

At Apúlia in north Portugal the Lower Ordovician sandstones ('Armorican Quartzite') include thin beds of calcareous sandstone which contain small (< 1 cm), hemispherical bodies with internal, concentric lamination. These bodies are regarded as being of algal origin. Does Professor Babin, or any of his colleagues, know of any similar occurrence of such algal beds in the Lower Ordovician of the Armorican Massif?

J. J. Chauvel. En Bretagne la Formation du Grès Armoricaïn contient des grès à ciment de carbonate de calcium qui semblent liés à la présence des niveaux de minerais de fer du Grès Armoricaïn inférieur. Dans ces grès le carbonate constitue toujours une partie du ciment, mais aucune structure attribuable à des algues n'a jusqu'à présent été mise en évidence.