PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

New Discoveries concerning the Geology of the Central and Eastern Parts of the English Channel

D. Curry and A. J. Smith

Phil. Trans. R. Soc. Lond. A 1975 **279**, 155-167
doi: 10.1098/rsta.1975.0048

Phil. Trans. R. Soc. Lond. A. **279**, 155–167 (1975) [155]
Printed in Great Britain

New discoveries concerning the geology of the central and eastern parts of the English Channel

By D. Curry and A. J. Smith
Department of Geology, University College London, W.C. 1

A study of rock-samples collected at 26 stations and continuous seismic profiles taken over a distance of 2000 km in the eastern part of the English Channel reveals the existence of a large flat-floored Tertiary syncline which forms an easterly extension of the Hampshire Basin of Southern England. The newly delineated basin, which is here referred to as the Hampshire–Dieppe Basin, forms part of the well-known Palaeogene Anglo-Paris-Belgian depositional basin. The total thickness of Palaeogene strata in the eastern part of the basin is about 380 m and the youngest beds present are probably of Upper Eocene age. Upper Cretaceous strata are exposed around the edges of the basin; the thickness of the Chalk varying from about 250 m in the south and east to 420 m in the northwest. The basin is bounded to the northeast by the Weald–Artois anticline and a strong flexure, the Bembridge–St Valéry line, which is a continuation of the Isle of Wight monocline, controls the position of much of its southwestern boundary.

To the south of the Hampshire–Dieppe basin lies the Baie de la Seine Tertiary syncline. Here, freshwater limestones of presumed Oligocene age overlie a Middle Eocene marine sequence.

Lithologies and microfaunas of the samples are described and related to those of sequences of similar age on nearby land, and some conclusions are drawn about the palaeogeography of the area. The geological structure of the area is elucidated, the paths of faults and fold axes are traced and a geological map is presented.

1. Introduction

The speculations of King (1949) about the geology of the eastern part of the English Channel led him to postulate the presence of a large synclinal area of Palaeogene beds in the centre of the region between Brighton, Le Havre and Le Touquet. The existence of this synclinal area was confirmed following the publication of the results of a geological survey carried out under the aegis of CNEXO (Centre National pour l'Exploitation des Océans) and that organization has published a series of geological maps based on their work. A short account of the stratigraphy and structure of the area surveyed is given by Robert (1971) and details of samples collected during the survey are contained in a series of articles by the Groupe Norois (1972). The present authors have made substantial use of the evidence provided by these samples in carrying out their present interpretation.

The researches on which the present paper is based were carried out during and following two short cruises in R.R.S. *John Murray* in December 1970 and January–February 1973 respectively. During the course of these cruises some 2000 km of continuous seismic profiler (c.s.p.) records were taken in a systematic exploration of the greater part of the eastern half of the English Channel (see figure 1). In addition 102 core-stations were manned from which 31 samples of bedrock were collected of which 27 are referred to in this paper. Position-fixing was by Decca Navigator. The low percentage of coring successes is due, in no small part, to the relatively thick deposits of superficial sediments which cover much of the area.

Preliminary examination of the seismic profiles made it clear that the area under examination is floored by well-bedded sedimentary strata showing low dips and only infrequent folding or faulting. Bands of strong and weak reflectors have been correlated from record to record and a particularly strong reflector which appears to be the top of the Chalk was especially valuable in this respect.

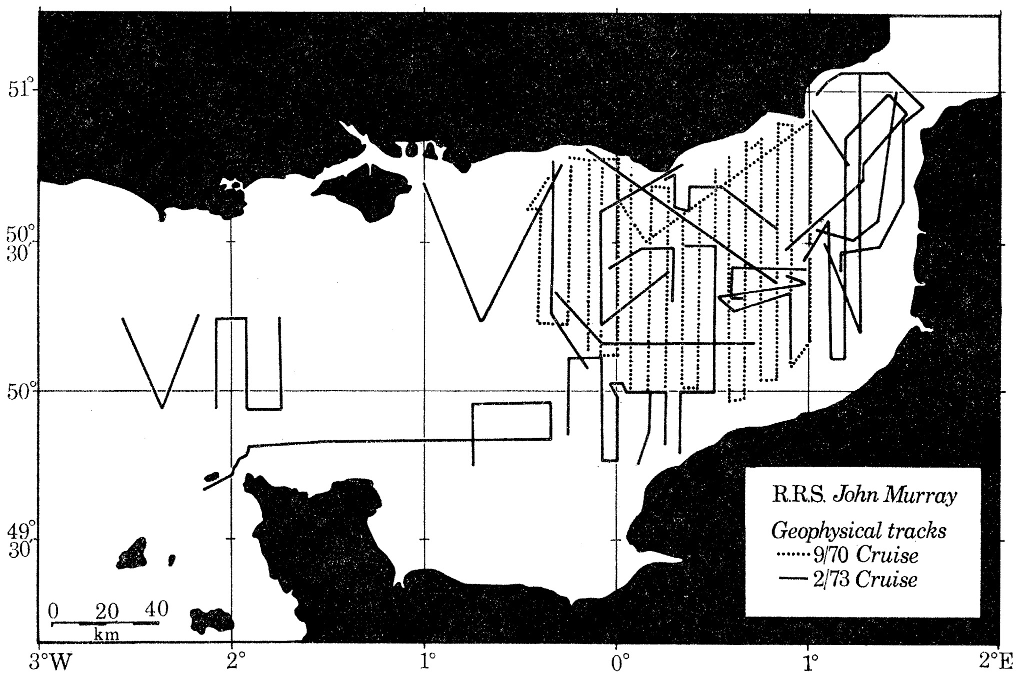

Figure 1. Continuous seismic profile traverses in the eastern part of the English Channel.

The greater part of the area investigated is occupied by a basin of Palaeogene strata which was named by Robert (1971) the Dieppe Basin. In his interpretation Robert incorrectly assumed that this basin was entirely surrounded by Upper Cretaceous beds. One result of the present authors' work has been to demonstrate that in fact the Dieppe Basin is connected directly with the Hampshire Basin, of which it forms the south-easterly prolongation. The authors have called this combined basin the Hampshire–Dieppe Basin; a name which acknowledges its location and extent. They consider it appropriate however to continue to use the separate names of Hampshire Basin and Dieppe Basin for the component parts of the newly defined basin where that course seems appropriate.

Bounded on the northeast by the Weald–Artois structure the Palaeogene strata of the Dieppe Basin are surrounded on the north, east and south by gently dipping Upper Cretaceous beds. The western limit of the basin is bounded in part by a structural line, the Bembridge–St Valéry line, which is described elsewhere (see Smith & Curry 1975). The Palaeogene successions extend westwards beyond this line however south of 50° 25′ N. The Dieppe Basin, like the Palaeogene outliers in the central English Channel, formed part of the originally uninterrupted extension of Palaeogene strata known as the Anglo-Paris-Belgian Basin.

2. Methods and results of detailed interpretation of c.s.p. records

On the basis of the c.s.p. records it was possible to build up a detailed map of the geological structure while the rock samples provided information which enabled the main reflecting horizons to be dated with more or less precision and permitted the sketching in of geological boundaries. The Chalk–Palaeogene boundary could be identified particularly readily. Because of the unbroken nature of the records and the presence on most of them of this boundary datum it was possible on most tracks to calibrate these with reference to it. By using the 10 ms time marks generated by the equipment, the time relation between each successive bed and the

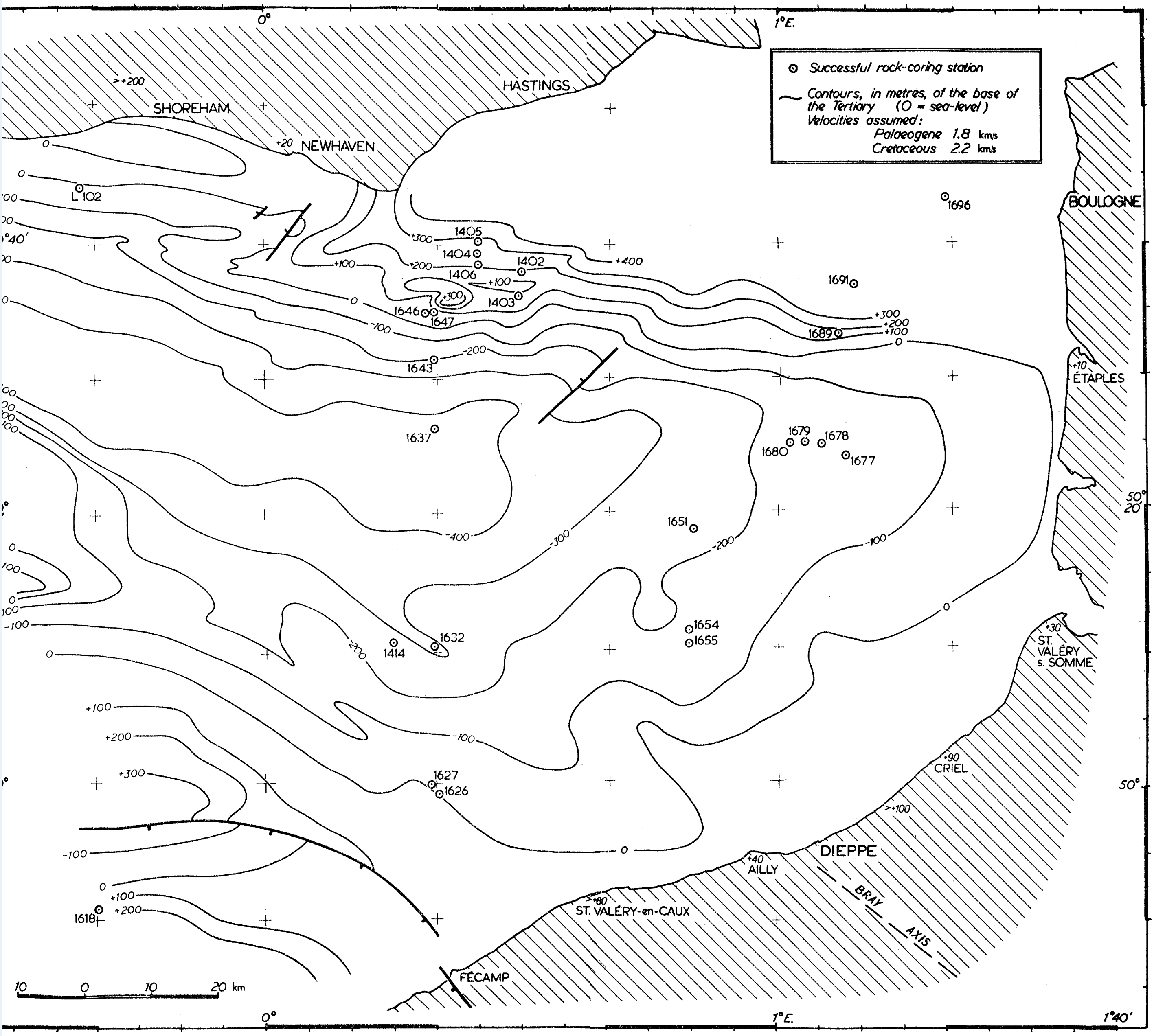

Figure 2. Contour map of the base of the Palaeogene in the eastern part of the English Channel, with records of successful rock-coring stations.

Chalk–Palaeogene junction was determined and a contour map was drawn by joining points of equal time-difference. Internal verification of the results was possible because the tracks form a grid and thus readings obtained at the same point from different tracks could be compared. In addition several tracks crossed the syncline from the Chalk–Palaeogene datum point in the north to that in the south. Two totals for the time-lapse were available in these cases from a single track. The pairs of results proved, on the whole, to be concordant. However, total time-lapses measured in the northern half of the syncline tended to be higher than those in the south, suggesting a southward thinning of the Palaeogene succession or some part of it. Identification of the base of the Chalk in some northern and western parts of the area permitted the making of estimates of the local thickness of the Chalk. It was established that a group of more powerful reflectors is present within the Palaeogene successions in the range approximately 150–300 ms two-way time above their base. These reflectors appear to be correlated with the existence of harder and more calcareous beds in the Lower and Middle Eocene parts of the succession, as proved by the characters of the samples collected there.

Estimates of thickness, based on time differences between specified marker horizons, have been made by postulating a mean velocity of 2.2 km/s for the Chalk and earlier beds and of 1.8 km/s for the Palaeogene. The choice of these velocities is based on unpublished work carried out at University College London on samples collected on land. Figure 2 is a plot of the contours

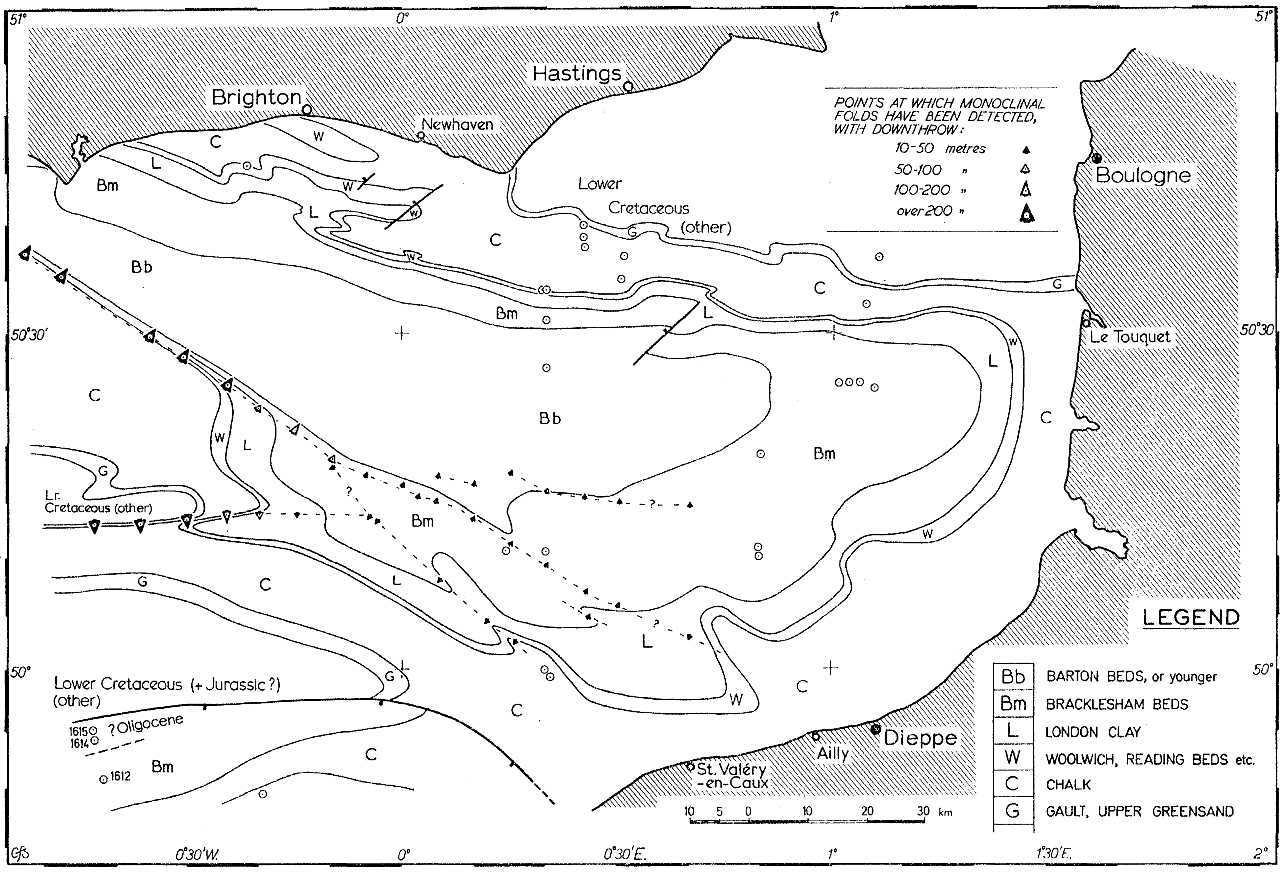

FIGURE 3. Provisional geological map of the eastern part of the Hampshire–Dieppe Basin, showing fault/fold systems in the area between the Isle of Wight and Dieppe.

of the base of the Palaeogene as determined from the c.s.p. records. The contour intervals have been chosen as 110 ms for the Palaeogene and 90 ms for the Chalk and earlier beds. The contour spacing in terms of rock thickness is thus 100 m throughout. Datum for the contour lines is present sea level. The combination of the datum lines provided by the c.s.p. records and the point stratigraphical information provided by core-samples collected by British and French teams has permitted the insertion of provisional boundaries on the geological map included as figure 3. The present authors acknowledge a considerable debt of gratitude to J.-P. Auffret of the University of Caen for his kindness in giving them access to unpublished information in relation to the area immediately to the north of the French coast between St Valéry and Dieppe (see Auffret, Bignot & Blondeau 1975). This information has been incorporated in figure 3.

3. Folds and faults

In the areas of exposure of pre-Upper Cretaceous beds folds and faults are numerous and as a result it is difficult to correlate them on adjacent c.s.p. records and hence to ascertain their direction of strike. Some, which could be traced with more or less certainty across three or more records, are marked on figure 3. In the main syncline of Chalk and Palaeogene beds dips are usually very low; folds, and especially faults, are infrequent. It is thus possible to trace them with more certainty and several linear features each tens of miles long have been observed. The most important of these is the easterly continuation of the Isle of Wight monocline. This is seen from c.s.p. records to curve gently towards the southeast and then to proceed almost linearly towards St Valéry-en-Caux. At the same time the amplitude of the displacement, which is about 1250 m at Culver Cliff, reduces southeastwards steadily but fairly rapidly, as do the maximum dips of the limb of the monocline. At about 50° 14′ N, 0° 10′ W, the feature appears to bifurcate. One fork, with a downthrow mostly to the north, proceeds along a bearing of about 118° towards Dieppe; the other, with a downthrow to the southwest, bears along 135° in the direction of St Valéry-en-Caux. The complementary monocline to that of the Isle of Wight (see Dignwall 1971), which lies E–W approximately along 50° 12′ N, appears to merge with the second of these lines. Plots of flexures believed to be associated with the structures just described are marked on figure 3, which demonstrates the linear pattern which these plots produce. It should be stressed that the true dip of the steeper face of each flexure in most cases is not known; only its dip in relation to the ship's track. On the map the directions of dip have been drawn at right angles to the plot of the postulated fold- or fault-line.

Another important W–E feature is a fault in the northern part of the Baie de la Seine which runs approximately along 49° 57′ N, curving east of 0° to the southeast and approaching the coast at Fécamp.

Each of these three structural features, those pointing to Fécamp, St Valéry and Dieppe respectively, appears to be a seaward continuation of a structure known on land. This fact is shown diagrammatically in figure 5 of Smith & Curry (this volume, p. 12) in which paper the significance of that observation is discussed.

4. Location, fauna and age of samples studied

(a) *Rock-samples collected in the eastern English Channel*

station number	latitude and longitude		lithology and estimated age	metres†
UCL1402	50° 38.0′ N,	0° 30.0′ E	Chalk, probably Coniacian	−220
UCL1403	50° 35.7′ N,	0° 30.2′ E	Chalk, Lower Cenomanian	−350?
UCL1404	50° 39.4′ N,	0° 25.1′ E	Chalk, Upper Cenomanian	−330
UCL1405	50° 40.2′ N,	0° 25.4′ E	Gault, Albian	−400
UCL1406	50° 38.6′ N,	0° 25.2′ E	Chalk, Upper Cenomanian or Lower Turonian	−300
UCL1424	50° 10.6′ N,	0° 15.0′ E	Calcareous sandstone, Lutetian	+280
UCL1612	49° 50.7′ N,	0° 42.2′ W	Marl, Upper Lutetian	+60
UCL1614	49° 54.1′ N,	0° 43.4′ W	Freshwater limestone, ?Oligocene	+130
UCL1615	49° 54.9′ N,	0° 43.8′ W	Freshwater limestone, ?Oligocene	+150
UCL1618	49° 51.0′ N,	0° 19.5′ W	Chalk, probably Senonian	−80
UCL1626	49° 59.4′ N,	0° 20.2′ E	Chalk, probably Santonian	−30
UCL1627	50° 00.0′ N,	0° 19.8′ E	Chalk, Santonian	−30
UCL1632	50° 10.6′ N,	0° 20.0′ E	Glauconitic sandy limestone, Lutetian	+220
UCL1637	50° 26.3′ N,	0° 20.1′ E	White sand, ?Upper Eocene	+350
UCL1643	50° 31.4′ N,	0° 20.3′ E	Glauconitic sand, Eocene	+180
UCL1646	50° 34.8′ N,	0° 19.0′ E	Chalk, Coniacian or later	−90
UCL1647	50° 35.1′ N,	0° 19.8′ E	Chalk, Coniacian	−100
UCL1651	50° 19.1′ N,	0° 49.8′ E	Glauconitic sandy clay, Eocene	+250
UCL1654	50° 11.3′ N,	0° 50.3′ E	Calcareous sandstone, Eocene	+150
UCL1655	50° 10.2′ N,	0° 49.4′ E	Nummulitic sandstone, Cuisian	+140
UCL1677	50° 24.5′ N,	1° 08.0′ E	Laminated sandy clay, Eocene	+180
UCL1678	50° 24.8′ N,	1° 06.1′ E	Glauconitic sandy clay, Cuisian	+180
UCL1679	50° 25.4′ N,	1° 03.8′ E	Glauconitic sandy clay, ?Cuisian	+180
UCL1680	50° 24.9′ N,	1° 02.0′ E	Glauconitic sandy clay, ?Cuisian	+180
UCL1689	50° 33.1′ N,	1° 07.1′ E	Chalk, Middle or Upper Turonian	−110
L102	50° 44.0′ N,	0° 24.5′ W	Chalk, Santonian–Campanian boundary	0

† Estimated position of the sample above (+) or below (−) the top of the Chalk.

(b) *Notes on rock-samples collected*

The locations of the great majority of the samples are within the Dieppe Basin and these are identified on figure 2. A group of three samples, numbers 1612, 1614 and 1615, was taken outside the basin and their sites are located in the Palaeogene syncline in the north of the Baie de la Seine. These are plotted on figure 3.

Comments on the lithology and palaeontology of individual samples follow:

Gault

1405 is a grey clay with small phosphatic nodules and well-preserved foraminiferids of about twenty species. These include the characteristic Gault species *Gyroidinoides* cf. *nitidus* (Reuss), *Gavelinella ammonoides* (Reuss) and *Hedbergella planispira* (Tappan). The small size of the specimens of the last-named species suggests that this sample came from the lower part of the Gault. Probably Middle Albian.

Chalk

Cenomanian. 1403 and 1404 are pale calcarenites with very abundant *Inoceramus* prisms and many foraminiferids including *Tritaxia tricarinata* (d'Orb), *Gavelinopsis turonica* (Brotzen), *Gavelinella baltica* Brotzen and *Hedbergella portsdownensis* (Williams-Mitchell). Planktonic foraminiferids are abundant in 1404 and include *Rotalipora cushmani* (Morrow). In 1403 planktonics are relatively rare but include *Rotalipora* cf. *appenninica* (Renz), while the benthonic form *Pseudotextulariella cretosa* (Cushman) is present. These facts suggest that 1403 is Lower or Middle Cenomanian and that 1404 is Upper Cenomanian.

Turonian

1406 is a hard white chalk with abundant calcareous spheres (*Calcisphaerula*) and *Pithonella*. Foraminiferids include *Pseudovalvulineria globosa* (Brotzen), *Gavelinopsis turonica*, *Hedbergella portsdownensis*, *Eouvigerina stormi* Brotzen and *Heterohelix* sp. The fauna indicates an Upper Cenomanian or Lower Turonian age but the abundance of spheres and the lithology suggest Lower Turonian. 1689 is a soft white chalk with fragments of *Inoceramus* and echinoderms and with a few bryozoans and ostracods. Foraminiferids are abundant and include double-keeled globotruncanids, an early form of *Globorotalites* (*G. pruvosti* Goel) and *Eouvigerina stormi* with gavelinellids of a Middle or Upper Turonian aspect and species of *Heterohelix* and *Praebulimina*. Turonian, Lata or Planus Zone.

Coniacian

1647 and 1402 are white chalks with *Inoceramus* and echinoderm remains. 1647 is especially rich in foraminiferids. Both yielded *Globorotalites* of a more advanced type than in 1689, together with *Anomalina infrasantonica* Balakhmatova, *Gavelinella thalmanni* Brotzen and *Reussella szajnochae* (Grzybowski). The overlapping occurrence of *A. infrasantonica* and *G. thalmanni* indicates the Coranguinum Zone, which is confirmed by the presence in the samples of an undescribed species of *Bolivina* which is known elsewhere only from that Zone. 1646 is superficial sand which has yielded abundant small foraminiferids, including *Stensioeina praeexculpta* (Keller), which indicates a Conician age or later. This sample may not have been taken from rock in place.

Santonian

Fragments of very hard chalk were recovered from stations 1626 and 1627. Two samples from 1626 yielded *Bolivinoides* of an early type (cf. *B. culverensis* Barr) and one of these samples and 1627 yielded *Pseudovalvulineria pseudoexcolata* (Kalinin), which is particularly characteristic of Lower Santonian beds.

Campanian

Sample L102 was collected by Dr J. C. Betts of Brighton and the authors are indebted to H. Wallace for submitting it for examination. It was collected by diving and is believed to have been taken at the junction with the overlying Palaeogene. It has yielded *Bolivinoides decoratus* (Jones), *Pullenia* sp. and *Pseudovalvulineria glabra* Goel. It is either high Quadratus Zone or low Mucronata Zone in age.

Senonian (*undifferentiated*)

Small fragments of chalk recovered at station 1618 yielded a few foraminiferids, none of which was of detailed stratigraphical significance.

Palaeogene

The samples are listed approximately in order of age; the oldest first:

1655. A glauconitic calcareous sandstone with frequent *Nummulites planulatus* Lk. and *Ditrupa*

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

and with relatively abundant microfossils. These were more or less overgrown with calcite, but the following were determined: *Cyamocytheridea mourloni* (Keij), *Schizocythere tessellata* (Bosquet), *Trachyleberis aculeata* (Bosquet), *Cytherura bambruggensis* Keij, *Cytheretta* sp., *Elphidium laeve* (d'Orb.) and *Fasciolites oblongus* (d'Orb.). Lower Eocene, Cuisian.

1654. Hard calcareous sandstone with abundant tubes of the worm, *Ditrupa*, and with ill-defined molluscan casts. Concentration of *Ditrupa* occur locally at several levels in the Palaeogene of the Anglo-Paris-Belgian area as, for instance, near the base of the London Clay, and in the Sables de Cuise, the Calcaire Grossier and the Upper Bracklesham Beds. They thus have little significance for dating. However as this sample appears from the c.s.p. records to have been taken at almost the same level as 1655 it is presumed to be, like the latter, Cuisian.

1677, 1678, 1679 and 1680. These are glauconitic sandy clays collected near to one another and at about the same stratigraphical level. They are believed to be of Cuisian age. 1677 is laminated and has yielded no fossils. 1678 contains molluscan fragments (?*Mesalia*) and a few very small foraminiferids, which include *Elphidium laeve*, *Epistominella* sp., *Angulogerina muralis* (Terquem), *Bulimina elongata* d'Orb., *Guembelitria triseriata* (Terquem) and rare globigerinids. Seed-coats of *Scirpus* are present. The faunule is closely matched in Fisher (1862) Bed IV (Cuisian) of the Lower Bracklesham Beds, Whitecliff Bay, Isle of Wight; the abundance of *G. triseriata* being especially significant. 1679 has yielded *Scirpus*, but no other fossils. 1680 has yielded a small number of microfossils overgrown with calcite which include the ostracods *Schizocythere tessellata*, *Cyamocytheridea* sp., *Hemicytherideis grosjeani* (Keij) and *Echinocythereis* sp. nov.?, together with unidentifiable species of the genera *Elphidium* and *Cibicides*.

1643 is a glauconitic sandy clay, collected at about 180 m above the base of the Palaeogene. It no doubt belongs to the same stratigraphical division as 1677, 1678, 1679 and 1680.

1424 is a glauconitic calcareous sandstone with abundant nummulites. Polyzoans present include species of the genera *Vincularia*, *Crisia* and *Poricellaria*, whilst amongst about ten species of ostracods the following were identified; *Schizocythere tessellata*, *Cyamocytheridea mourloni*, *Leguminocythereis striatopunctata* (Roemer) and *Cytheretta costellata* (Roemer). About 25 species of smaller foraminiferids are present, mostly forms known in the Lutetian of the Paris Basin. Noteworthy are *Cibicides westi* Howe, *Pararotalia inermis* (Terquem), '*Amphistegina*' *nucleata* Terquem, *Asterigerina campanella* (Gümbel), *Reussella terquemi* Cushman, *Elphidium laeve* and rare *Globigerina* cf. *linaperta* Finlay. *Nummulites laevigatus* (Brug.) and *N. variolarius* Lk. are abundant and their coexistence in the sample indicates that it is of Middle Lutetian age. One very worn specimen of *Nummulites planulatus* was found and is no doubt derived.

1632 is a buff calcareous fine sandstone with glauconite and some quartz-grit, together with a high proportion of biogenic material. Larger Foraminifera include abundant *Nummulites laevigatus* with rare *N. variolarius* and *N. planulatus*, the last no doubt derived; also *Fasciolites* cf. *bosci* (Defr.) and fragments of *Orbitolites*. Smaller foraminiferids are poorly preserved but include several species of miliolids with *Rotalia trochidiformis* Lk., *Epistomaria rimosa* (Parker & Jones) and '*Amphistegina*' *nucleata*. Ostracods, polyzoans and calcareous algae are also present. Middle or, perhaps, Upper Lutetian.

1612 is a pale marl composed of about equal parts of quartz grains and biogenic material, mostly foraminiferids. Nummulites were not observed. It contains basically the same fauna of small foraminiferids and polyzoans as 1424 with, in addition 18 species of miliolaceans, including *Spirolina* and an abundance of species believed to have an attached mode of life, including *Orbitolites complanatus* Lk., *Cycloloculina punctata* (Terquem) and *C. eocenica* (Terquem). About

30 species of ostracods were recognized and are mostly of spinose or ornate types. The whole is clearly a sea-meadow fauna and matches those of certain Upper Lutetian localities in the Paris Basin.

1651 is a glauconitic clayey fine sand with infrequent *Nummulites variolarius* and with fragments of oysters and the mollusc *Amusium corneum* (J. Sby.). Microfossils are not common but include the ostracod *Leguminocythereis striatopunctata* and the following foraminiferid species: *Globulina gibba* and var. *punctata* d'Orb., *Guttulina problema* (d'Orb.), *Ammonia propingua* (Reuss), *Elphidium latidorsatum* (Reuss), *Reussella terquemi* and *Cibicides* spp. *A. propingua* and *E. latidorsatum* first appear in the Upper Bracklesham Beds and their equivalents and this fact in association with that of the presence of *N. variolarius* indicates an Auversian age.

1637 is a white medium sand with rare glauconite grains. It yielded a few small foraminiferids, *Asterigerina* sp. and *Cibicides* sp. together with spicules of ?*Geodia*. It may be of Upper Eocene age.

Stations 1614 and 1615 yielded angular fragments of hard buff limestone with freshwater gastropods of the genera *Planorbis* and ?*Hydrobia*. In addition, one fruit of a charophyte was observed. The c.s.p. records indicate that these samples were taken at a stratigraphical level about 80–100 m above sample 1612, which is dated as Upper Lutetian. The samples have yielded no direct indication as to their age but on the basis of their relation to 1612 they are provisionally dated as Oligocene. As mentioned earlier, samples 1612, 1614 and 1615 were taken in the syncline to the north of the Baie de la Seine.

5. General stratigraphy

In this section the stratigraphical information in the eastern English Channel as a result of this and previous investigations is considered in relation to that of the surrounding land areas. Comparisons are made of lithologies, thicknesses and faunal distributions and some comments are made on palaeogeography.

The lithology and faunas of the samples of Upper Cretaceous rocks collected are similar to those found nearby on land. The highest zone of the Chalk present south of Worthing (sample L102) is high Quadratus or low Mucronata and to the south of Beachy Head it is probably Lower Santonian. This deduction follows from the dating of 1647 as Coranguinum Zone and the observation that 1647 is about 90 m below the top of the local Chalk succession. The estimated thickness of the Chalk in the region of 1647 is about 350 m. All of these observations are consistent with what is known on the nearby Sussex coast. Farther east, near sample 1689, the thickness of the Chalk has not been accurately determined but may be about 250 m. 1689 is Middle or Upper Turonian and is about 110 m below the top of the local Chalk sequence. The highest Chalk present may thus be of Coranguinum or Uintacrinus age. This suggestion also is consistent with records on land; a sample of Chalk taken immediately below the Palaeogene at St Aubin, 8 km southeast of Le Touquet appears to be referable to the Coranguinum Zone.

To the south of the main Palaeogene syncline the only samples dated by the authors are 1626 and 1627, believed to be Santonian. These samples were taken about 30 m below the top of the Chalk. The total thickness of the Chalk in this area is not known. Farther west, in the region of 49° 50′ N, 0° 05′ W, about 250 m is present and to the northwest again at 50° 08′ N, 0° 15′ W, the thickness has risen to about 420 m; which thickness is about the same as is found at the eastern end of the Isle of Wight. No samples have been dated in these regions, so it is not known whether the difference between the two areas is due to a southward thinning or to pre-Palaeogene erosion.

Juignet & Kennedy (1974) have described from the Chalk of the region of Étretat (Seine-Maritime) a series of domed structures which they interpret as bioherms and which are confined to high Turonian and low Coniacian levels. Apparently identical structures have been recognized on c.s.p. records taken by University College London. The domes observed are typically 10–20 m high and 500–1000 m across and occur in some cases in layers in a band up to a total thickness of 50 m. In any sequence no more than one such band has been identified and it lies at a distance of about 100–200 m above the base of the Chalk. The structures have been observed at 12 sites in a region bounded by 49° 40′ and 50° 30′ N and 0° and 1° 10′ W. They have not been seen either in the region to the northeast of the Dieppe Basin or in the western English Channel.

The present authors cannot at this stage point with any conviction to the cause of these structures but it seems possible that they may be related to minor tectonic movements in what is an area of considerable tectonic complexity – see Smith & Curry (1975). These movements could have provided the shallower water conditions which Juignet & Kennedy suggest permitted the accumulation of the bioherms. These same movements would be associated with earthquakes and the latter could be the cause of the dewatering and slump structures associated with the supposed bioherms.

The Palaeogene samples recovered may be compared with those of the relatively complete successions in Belgium, the Paris Basin and the Isle of Wight, and with the restricted sequences at Newhaven, Sussex, and on the coast of France between Le Touquet and Ailly, near Dieppe (for an account of the latter see Feugueur (1963), pp. 406–409, 444–446). The succession at Ailly is the most complete of the nearby land sequences and displays Thanetian white marine sands, overlain by a continental limestone and this by Sparnacian grey estuarine clays and shelly sands. Overlying the Sparnacian sequence is a dark grey marine clay, the Formation de Varengeville, which presents many analogies with the London Clay. The total thickness of Palaeogene beds present appears to be no more than 30 m.

Amongst the present authors' samples there are none which can be compared with any part of the succession at Ailly. This is not surprising because no samples were taken near the base of the Palaeogene sequence seawards of Dieppe. The oldest sample, as determined by the co-occurrence of *Nummulites planulatus* and *Fasciolites oblongus*, is of Cuisian age and was taken at about 140 m above the base. The occurrence in this sample of *F. oblongus* is of particular interest as this species is common in the Sables de Cuise but is not known from approximately equivalent levels in Belgium or from the Hampshire area. The group of samples 1677–1680, taken at a slightly higher level (+180 m) can be closely matched both in lithology and fauna with Fisher Bed IV and its equivalents, the so-called Cuisian levels of the Hampshire area. It had been suspected (Curry 1967, p. 453) that Fisher Bed IV is somewhat younger than the type Sables de Cuise and these Channel records give support to this view.

Samples 1424 and 1632 yield both *N. planulatus*, *N. laevigatus* and *N. variolarius*. *N. planulatus* is a Lower Eocene species which is believed to be an ancestor of the Middle Eocene *N. laevigatus*. It occurs in rock-forming quantities at some horizons of the Lower Eocene Sables de Cuise and is found in the Paris Basin as a derivative in most subsequent transgressive horizons of the Palaeogene. It also occurs locally as a derivative in the Bruxellian of Belgium, as at Jodoigne. In England *N. planulatus* occurs rarely as a derivative in Fisher Bed 21 of the Upper Bracklesham

Beds of Selsey, Sussex, together with even rarer *N. laevigatus*, also derived. In the Paris Basin the source of the derivatives was presumably to the south. The *N. planulatus* in samples 1424 and 1632 are no doubt derived and the source of these derivatives and those in Fisher Bed 21 is probably to be found in the west. Throughout the whole of the western English Channel the Middle Eocene rests with non-sequence on Palaeocene or earlier beds, the Lower Eocene having been identified only west of 5° 30′ W. Little is known about the succession in the Palaeogene outlier north of the Baie de la Seine but as Middle Eocene beds occur there at only 60 m above the top of the Chalk (sample 1612) the Lower Eocene is probably missing in that area also. There must have been a sea link between the Anglo-Paris-Belgian area and the southwest in Lower Eocene times via the western English Channel to have allowed the immigration of forms of Tethyan origin such as *N. planulatus*, *Fasciolites oblongus* and *Cuvillierina*. Marine beds then deposited in that seaway were no doubt destroyed by Middle Eocene downcutting or transgression and could have provided the derived *N. planulatus* recorded in 1424 and 1632.

The occurrence together in sample 1632 of *Fasciolites* and *Orbitolites* with *N. laevigatus* is worthy of comment. In the Paris Basin *N. laevigatus* is present only in the lower part of the Calcaire Grossier (though it may be absent from the very lowest beds of that formation) and *Fasciolites bosci* and *Orbitolites complanatus* occur only in the upper part (Abrard 1925, p. 247). *N. laevigatus* in sample 1632 is abundant and well preserved and appears not to be derived. It is reported elsewhere in this publication (Curry, this volume, p. 99) that species of foraminiferids with restricted ranges in the Anglo-Paris-Belgian area may have longer ranges in the western English Channel and the occurrence in 1632 appears to be a similar case. The presence or absence of a small number of selected species of larger foraminiferids has been used for correlation purposes within the Anglo-Paris-Belgian area. Discoveries such as that in 1632 emphasize the need for caution in making correlations on a restricted number of species and the desirability of corroboration based on a wide spectrum of organisms in cases of doubt.

All of the samples of rock of Eocene age collected at sea by the present authors in the Hampshire–Dieppe syncline are of marine origin and they are dominantly glauconitic and contain more or less clay. In these characters they resemble most closely the sequences of corresponding age in Belgium, the London Basin and the eastern part of the Hampshire Basin. There is less resemblance to the sequences in the Paris Basin, which contain many intercalations of continental deposits and where marine sandy clays and glauconite are infrequent.

It has not yet proved possible to sample the youngest Palaeogene beds present in the Dieppe syncline. Sample 1637, taken at perhaps 30 m below the highest beds present has unfortunately yielded only a very restricted fauna which cannot be dated precisely. It is clearly fully marine however and is most probably Upper Eocene. The beds overlying this level show no indication of a stratigraphical break on the c.s.p. records and it thus seems unlikely that any Oligocene strata are present as suggested by Robert (1971, p. 39).

An attempt has been made in figure 4 to compare the thicknesses of Palaeogene beds in various parts of the Anglo-Paris-Belgian area. Thicknesses for the submarine sequences are estimated from c.s.p. records. It will be noted that the thickness of beds in the eastern part of the Hampshire–Dieppe syncline is intermediate between those of the Hampshire Basin and of the region north of the Artois axis, for which area the section at Cassel has been taken as typical. The sharp reduction of thicknesses southwards from the Isle of Wight is very apparent. It seems too that there must be non-sequences in the syncline to the north of the Baie de la

Seine which was first reported by Dingwall (1969). The situation there shows strong parallels with those in the Cotentin peninsula and in the western part of the English Channel south of the Hurd Deep (Andreieff *et al.*, this volume, pp. 87–89). The deepest part of the trough extending in earlier Palaeogene times from the continental slope through to Belgium appears in fact to have followed the course of the northern part of the present English Channel, while to the south on and near the Cotentin peninsula was a high-standing area on which marine deposition was only intermittent.

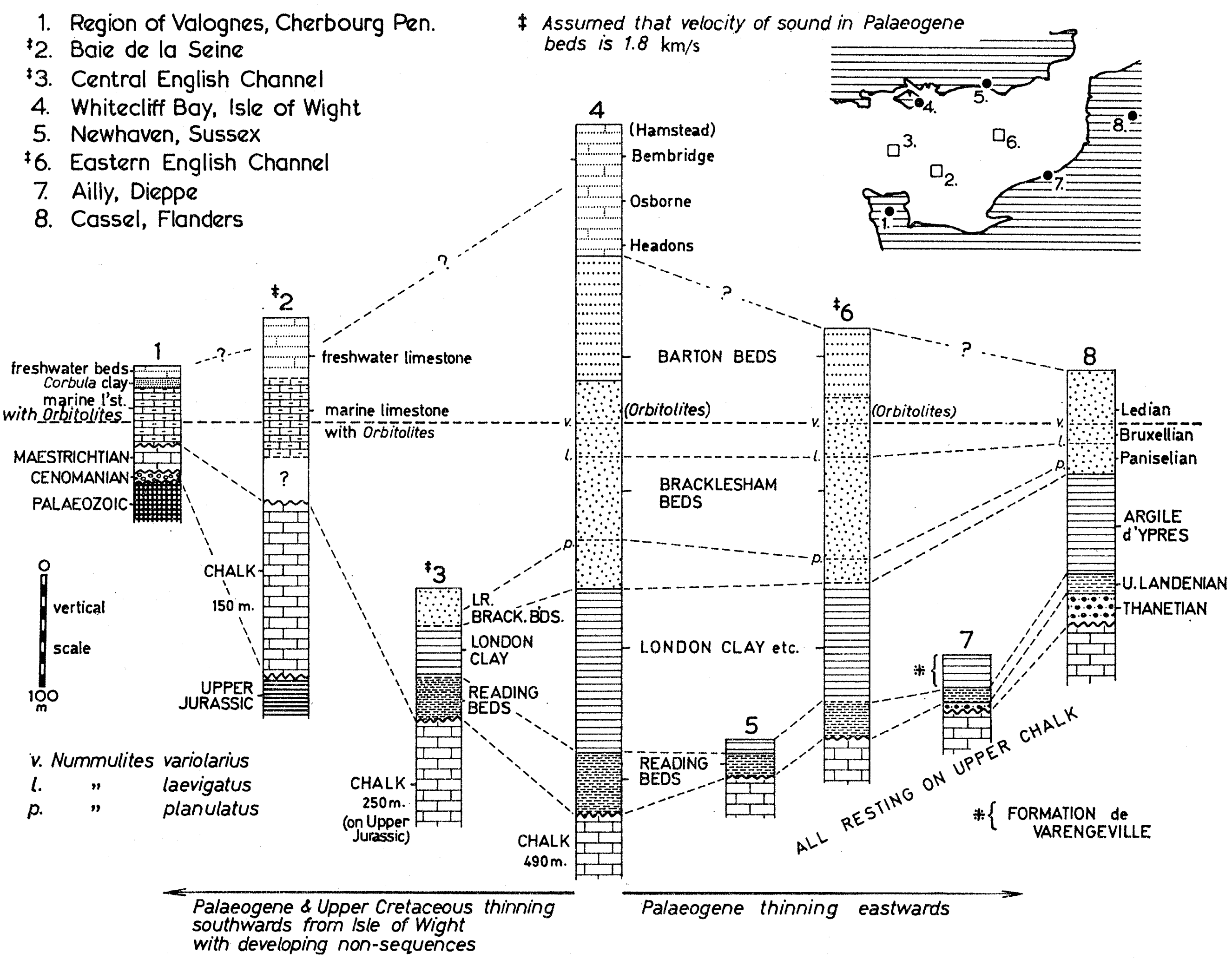

FIGURE 4. Tentative correlations between Palaeogene sequences in the central and eastern English Channel and those on nearby land.

The discovery in the Baie de la Seine syncline of freshwater limestone of presumed Oligocene age (samples 1614, 1615) parallels a similar one, more certainly dated as Oligocene, south of the western end of the Hurd Deep (see Andreieff *et al.*, this volume, p. 89). Possibly the greater part of the English Channel area was land at this time; such a land link would explain the close similarity between the assemblages of mammals, continental molluscs and charophytes of the Hampshire Basin and France in latest Eocene and early Oligocene times.

The authors express their grateful thanks to the Natural Environmental Research Council for the provision of ship time on R.R.S. *John Murray*. They much appreciate too the helpful and willing cooperation of all those with whom they sailed in her in the course of the present researches; a special word of thanks is due to those colleagues and students of University College who from time to time gave assistance beyond the ordinary call of duty in that connexion.

References (Curry & Smith)

Abrard, R. 1925 *Le Lutétien du Bassin de Paris*. Angers: Société française d'Imprimerie d'Angers.

Andreieff, P., Bouysse, P., Curry, D., Fletcher, B. N., Hamilton, D., Monciardini, C. & Smith, A. J. 1975 Stratigraphy of post-Palaeozoic sequences in part of the western Channel (map – Guernsey 1:250000). *Phil. Trans. R. Soc. Lond.* A **279**, 79–97 (this volume).

Auffret, J. P., Bignot, G. & Blondeau, A. 1975 Géologie du Bassin tertiaire de la Manche orientale au large du Pays de Caux. *Phil. Trans. R. Soc. Lond.* A **279**, 169–176 (this volume).

Curry, D. 1967 Problems of correlation in the Anglo-Paris-Belgian Basin. *Proc. Geol. Ass., Lond.* **77**, 437–467.

Curry, D. 1975 *Phil. Trans. R. Soc. Lond.* A **279**, 99–107 (this volume).

Dingwall, R. G. 1971 The structural and stratigraphical geology of a portion of the eastern English Channel. *Inst. geol. Sci. Rep.* no. 71/8, 24 pp.

Feugueur, L. 1963 L'Yprésien du Bassin de Paris. *Mém. Serv. Carte géol. dét. Fr.* Paris: Imprimerie nationale.

Fisher, O. 1862 On the Bracklesham Beds of the Isle of Wight Basin. *Q. Jl geol. Soc. Lond.* **18**, 65–94.

Groupe Norois 1972 Contribution a l'étude stratigraphique des terrains affleurant en Manche centrale et orientale. *Mém. Bur. Rech. géol. min.* **79**, 123–170.

Juignet, P. & Kennedy, W. J. 1974 Structures sédimentaires et mode d'accumulation de la craie du Turonien supérieur et du Sénonien du Pays de Caux. *Bull. Bur. Rech. géol. min.*, (2), section IV, no. 1–1974, pp. 19–47.

King, W. B. R. 1949 The geology of the eastern part of the English Channel. *Q. Jl geol. Soc. Lond.* **104**, 327–337.

Robert, J. P. 1971 Results of a sparker reconnaissance survey of the eastern and central English Channel. In F. M. Delany (ed.), The geology of the East Atlantic Continental Margin. 3. Europe (continued). *Inst. geol. Sci. Rep.* no. 70/15, pp. 35–41.

Smith, A. J. & Curry, D. 1975 The structure and geological evolution of the English Channel. *Phil. Trans. R. Soc. Lond.* A **279**, 3–20 (this volume).