meteorites[9-11], the transformation conditions (P, T and differential stress) are unknown. Our work provides evidence that this mechanism could occur under mantle conditions. The transformation mechanism is potentially of considerable importance for mantle rheology, and therefore mantle dynamics, because if transformation occurs between β-phase and spinel by the martensitic mechanism, the shear strength should be greatly reduced during the transformation[3,10]. Transformation plasticity may also occur during a diffusion-controlled transformation, but the mechanism and magnitude of the effect will be different[4,22]. In either case, a zone of decoupling at the phase boundary in the mantle is a possibility[6] and the rheology and dynamics of mantle plumes could also be affected as rising material crosses from the stability field of spinel to that of the β-phase. The details of the dependence of the different nucleation and growth mechanisms on P, T and differential stress have yet to be investigated. Our results together with those of Remsberg and Liebermann[21] suggest, however, that at the β/γ phase boundary, where temperatures are ~1,500 °C[23], transformation will occur close to equilibrium by the diffusion-controlled mechanism.

By analogy with our results, the mechanism of the β-to-γ transformation is also likely to vary with pressure and temperature. Madon and Poirier[11] have shown that the energetics of a martensitic β-to-γ transformation are similar to those of the reverse transformation studied here. The martensitic β-to-γ transformation would involve the propagation of $1/2[\bar{1}01](010)$ partial dislocations on every alternate (010) plane of β-phase[10,11] and would also be likely to result in a large reduction in shear strength. This mechanism is most likely to operate in subducting slabs where low temperatures inhibit a diffusion-controlled mechanism. Such martensitic transformation could have an important effect on the rheology of the slab In addition, if the martensitic mechanism operates in subducting slabs under high differential stress, the transformation could occur very rapidly. Rapid transformation with an associated reduction in strength could result in shear instabilities and thus in deep-focus earthquakes. The occurrence of acoustic emissions during rapid martensitic transformations in Si and Ge at high pressure in the diamond-anvil cell has also led to the proposal that martensitic transformations could be the cause of some deep-focus earthquakes in subducting slabs[24]. □

Received 20 July; accepted 24 October 1990.

1. Jeanloz, R. & Thompson, A. B. *Rev. Geophys. Space Phys.* **21,** 51–74 (1983).
2. Bina, C. R. & Wood, B. J. *J. geophys. Res.* **92,** 4853–4866 (1987).
3. Poirier, J. P. *J. geophys. Res.* **87,** 6791–6797 (1982).
4. Rubie, D. C. in *Deformation Processes in Minerals, Ceramics and Rocks* (eds Barber, D. J. & Meredith P. G.) 262–295 (Unwin Hyman, London, 1990).
5. Christensen, U. R. & Yuen, D. A. *J. geophys. Res.* **90,** 10291–10300 (1985).
6. Parmentier, E. M. *Geophys. Res. Lett.* **8,** 143–146 (1981).
7. Kirby, S. H. *J. geophys. Res.* **92,** 13789–13800 (1987).
8. Green, H. W. & Burnley, P. C. *Nature* **341,** 733–737 (1989).
9. Price, G. D., Putnis, A. & Smith, D. G. W. *Nature* **296,** 729–731 (1982).
10. Price, G. D. *Phys. Earth planet. Inter.* **33,** 137–147 (1983).
11. Madon, M. & Poirier, J. P. *Phys. Earth planet. Inter.* **33,** 31–44 (1983).
12. Ito, E., Takahashi, E. & Matsui, Y. *Earth planet. Sci. Lett.* **67,** 238–248 (1984).
13. Remsberg, A. R., Boland, J. N., Gasparik, T. & Liebermann, R. C. *Phys. Chem. Minerals* **15,** 498–506 (1988).
14. Ito, E. & Takahashi, E. *J. geophys. Res.* **94,** 10637–10646 (1989).
15. Brearley, A. J., Rubie, D. C. & Ito, E. *Phys. Chem. Minerals* (submitted).
16. Vaughan, P. J. & Kohlstedt, D. L. *Phys. Chem. Minerals* **7,** 241–245 (1981).
17. Kohlstedt, D. L. & Weathers, M. S. *J. geophys. Res.* **85,** 6269–6285 (1980).
18. Burnley, P. C. & Green H. W. *Nature* **338,** 753–756 (1989).
19. Plichta, M. R., Clark, W. A. T. & Aaronson, H. I. *Metall. Trans.* A**15,** 427–435 (1984).
20. Porter, D. A. & Easterling, K. E. *Phase Transformations in Metals and Alloys* (Van Nostrand Reinhold, Wokingham, 1981).
21. Remsberg, A. R. & Liebermann, R. C. *Phys. Chem. Minerals.* (submitted).
22. Poirier, J. P. *Creep of Crystals* (Cambridge University Press, 1985).
23. Ito, E. & Katsura, T. *Geophys. Res. Lett.* **16,** 425–428 (1989).
24. Meade, C. & Jeanloz, R. *Nature* **339,** 616–618 (1989).
25. Akoagi, M., Ito, E. & Navrotsky, A. *J. geophys. Res.* **94,** 15671–15685 (1989).
26. Rubie, D. C. *et al. J. geophys. Res.* **95,** 15829–15844 (1990).

ACKNOWLEDGEMENTS. We thank E. Ito for assistance with the high-pressure experiments, which were performed at Okayama University. Electron microscopy was carried out at the Electron Microbeam Analysis Facility, Department of Geology and Institute of Meteoritics, University of New Mexico. We thank H. W. Green for a review, and S. H. Kirby, S. Seifert and S. L. Webb for comments. This work was partially funded by NERC(D.C.R.) and NASA (K. Keil).

Evidence for reflectors in the lower continental crust before rifting in the Valencia trough

A. B. Watts*§, M. Torné*§||, P. Buhl*, A. Mauffret†, G. Pascal‡ & B. Pinet‡

* Lamont-Doherty Geological Observatory, Palisades, New York 10964, USA
† Université Pierre et Marie Curie, 4 Place Jussieu, Cedex 75252, Paris, France
‡ Institut Français du Pétrole, Cedex 92506, Rueil-Malmaison, France

THE past decade has seen a rapid advance in our understanding of the deep structure of the continental crust, especially in Europe[1-3], Australia[4] and North America[5], where seismic profiling has revealed a highly reflective layer in the lower crust. On many profiles, the reflective layer is associated with regions of extension[6,7], suggesting that the reflectors originate by some form of ductile flow or magmatic intrusion during rifting[8,9]. To test this hypothesis, we have examined geophysical and geological data from the Valencia trough, a rift basin[10-12] of Late Oligocene/Early Miocene age. From a comparison of profiles in different parts of the trough, and independent constraints on the initial crustal thickness, we argue that the reflective layer in this basin was probably already in the crust before rifting, and that a mid-Tertiary extensional event is not required to explain it.

In November 1988, a two-ship (R/V *Robert D. Conrad* and N/O *Jean Charcot*) multichannel seismic reflection and refraction experiment was carried out in the Valencia Trough off the northeast coast of Iberia. The data include a 110-km-long common depth point (CDP) line 819 on the shelf, a 30-km-long CDP line 815 on the slope and a 100-km-long expanding spread profile (ESP 6) that crosses both the shelf and slope (Fig. 1). CDP line 819 and ESP 6 were shot normal to a steep gradient of the Bouguer gravity anomaly which marks[13] the transition from the thick crust of Iberia to thin crust beneath the trough. Both ships were equipped with a 96-channel 2.4-km-long streamer, satellite navigation, and precision gravity and depth recorders. The 10-airgun tuned array of the *Conrad* was used as the source for both the CDP and ESP experiments.

Figure 2 shows a migrated 96-fold stack along line 819 together with results of velocity modelling at ESP 6. We used standard processing techniques[14] and stacking velocities based on sonic velocities from nearby commercial wells. The well data[15] indicates that the sedimentary layer is 3–4 km thick and of Early Miocene to Recent age. Underlying the sediments is a strong continuous reflector (2.2 s) which marks the surface of an eroded Mesozoic carbonate platform. Below this reflector, there is a thick, acoustically transparent layer with few internal reflectors. At a two-way time (TWT) of ~6.2 s, there is an abrupt development of subhorizontal lower crustal reflectors, which appear continuous on horizontal length scales of up to 15 km. Along parts of the profile, the reflective crust is characterized by lozenge-shaped transparent zones and concave-up cross-cutting reflectors. The reflectors end sharply at ~8 s where they pass into a strong continuous reflector which we interpret as the 'reflection' Moho. The average p-wave (compressional) velocities V_p of the upper and lower crustal layers at ESP 6 (Fig. 2) are 6.1 and 6.7 km s^{-1}, respectively, indicating a total crustal thickness (excluding sediments) along the line of 18–19 km.

Similar lower crustal reflectors have already been identified elsewhere in Europe[1-3,16-20]. Typically[21], these reflectors occur

---

§ Present address: Department of Earth Sciences, University of Oxford, Parks Road, Oxford OX1 3PR, UK.

|| Also at: Institute of Earth Sciences, Barcelona, Spain.

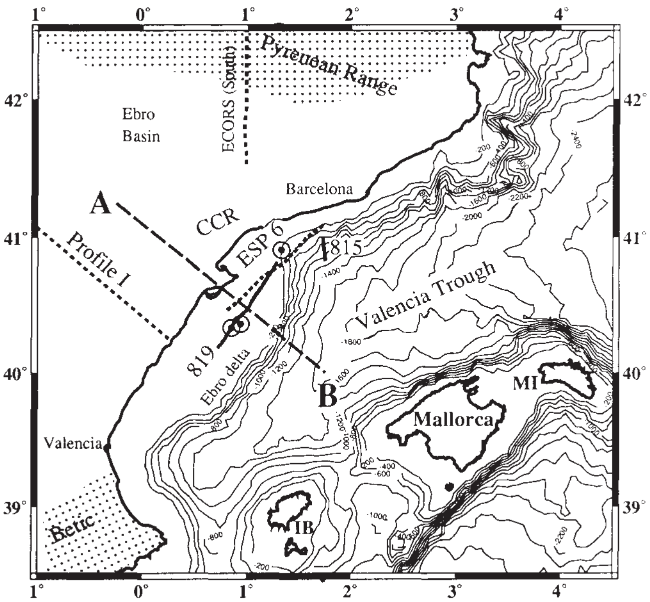


FIG. 1 Location map of the Valencia trough and vicinity. Topography[39] at 200-m interval. The solid lines show the location of CDP lines 819 and 815. The heavy dashed line shows the cross-section AB based on seismic and gravity modelling, the lighter dashed lines show the seismic refraction profiles I[22] and ESP 6, and the seismic reflection profile ECORS Pyrenees South line[37]. The filled circles show the wells used in Fig. 4. The wells from north to south are: 466, 419 and 299. CCR, Catalan Coastal Ranges; MI, Menorca; IB, Ibiza.

at a TWT of 5-7 s (15-21 km depth), have high average V_p (6.6-7.8 km s^{-1}) and are especially well developed in regions dominated by extensional tectonics.

Previous seismic refraction studies[22] indicate crust 30-35 km thick beneath Iberia which, together with our results (Fig. 2), suggests at least 9 km of crustal thinning towards the Valencia trough. Were the reflectors generated by the same extensional event that formed the trough, were they added to it later, or were they already in the crust before extension? If the deep layers were produced in some way by extension, we would expect, following the arguments of Peddy *et al.*[23], the intensity of reflectors to increase towards the trough axis because this would be a region of thinner, more stretched crust.

Figure 3 shows part of line 815, which was shot at depths of ~800 m. This line does not show a highly reflective lower crust. Instead, there is a single continuous reflector at a TWT of ~8 s which is similar to the 'reflection' Moho on line 819 and to reflectors identified elsewhere[24] in the trough. We do not believe that the absence of reflectors in Fig. 3 is caused by a decrease in signal-to-noise ratio as the depth increases, scattering owing to the relief of the Messinian erosional discordance, or by lack of multiple suppression, although these factors may contribute. Rather, their absence suggests that the reflectors beneath the shelf were either pre-existing and a subsequent extensional event reduced their thickness beneath the trough or that they were added later by magmatism, which preferentially underplated[25] or intruded the shelf rather than the trough.

The crustal thinning at the time of rifting has been estimated by backstripping[26] the Late Oligocene/Early Miocene to Recent sedimentary section at three commercial wells drilled along line 819. The total tectonic subsidence (TTS)[27], which is in the range 1.4-1.6 km, could be explained by an instantaneous-stretching model[28] with an age of rifting of 25 Myr and a stretching factor of $\beta = 1.40$-1.55 but, a better fit to the subsidence history was obtained (Fig. 4) using a finite-stretching model[29,30] with a similar β and a rifting duration of 8-24 Myr. Evidence that rifting in the Valencia Trough may have been a protracted event is seen in the occurrence of calc-alkaline volcanic rocks of early Miocene to middle Pleistocene age in Deep Sea Drilling Project sites in the trough[31] and outcrop on the Columbretes Islands[32]. A stretching factor of 1.40-1.55 implies a crustal thickness of 20-22 km along line 819, assuming an initial crustal thickness of 31.2 km.

Figure 5 shows a crustal cross-section (profile AB) from the Ebro basin to the trough axis which is constrained by seismic, gravity anomaly and well data. The hatchured lines (lower panel) show prominent discontinuities in V_p along seismic refraction profiles I[22] and ESP 6 (Fig. 2). The mantle velocity of 7.8 km s^{-1} is low when compared to velocities[22] beneath Iberia but, is similar to velocities beneath active 'continental' rifts such as

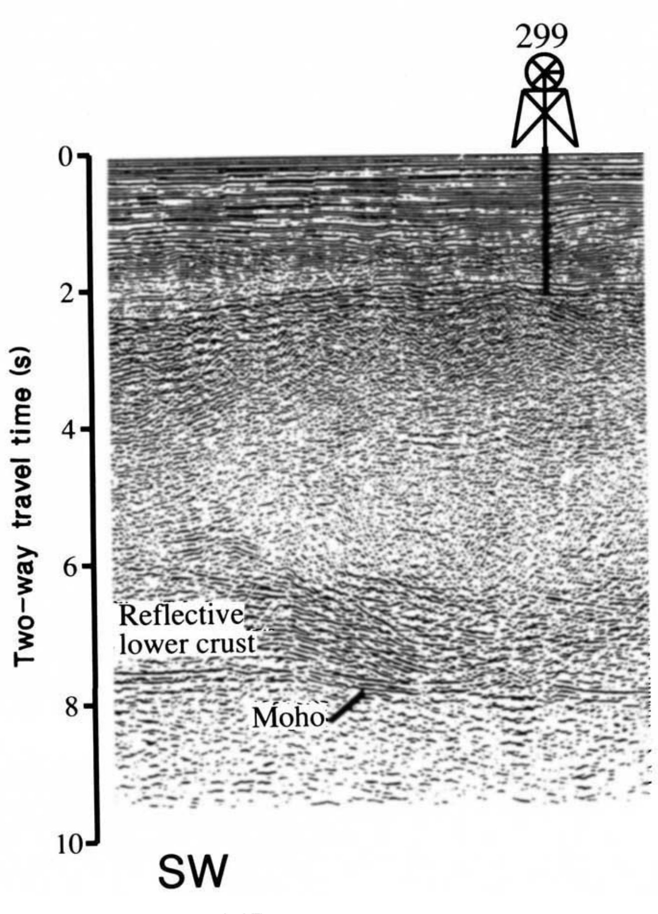
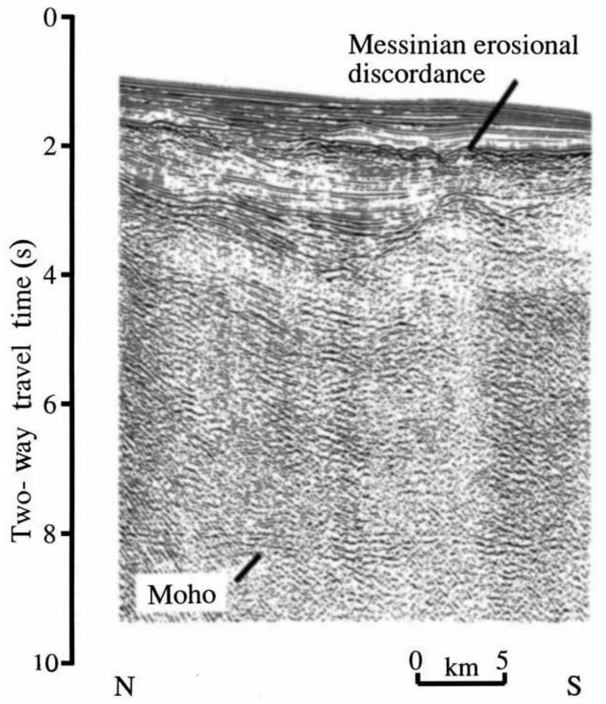


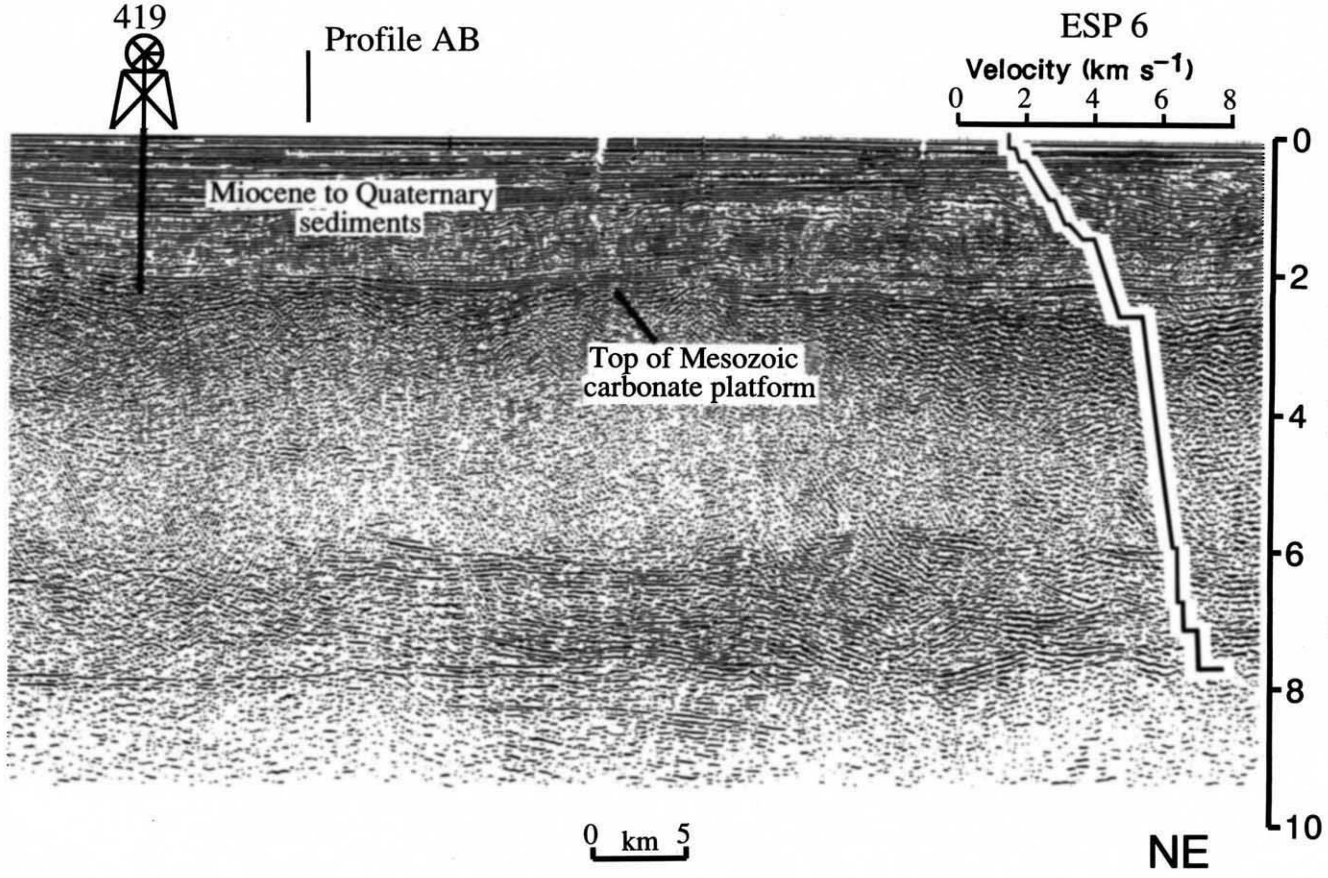
FIG. 2 Migrated 96-fold CDP line 819. The location of wells 299 and 419, the intersection of profile AB and the mid-point of ESP 6 are shown above the profile. The thick line at the end of the profile shows the velocity-TWT function deduced from modelling the data obtained along ESP 6 in the τ-p and X-T domains[40]. The lower continental crust is associated with V_p = 6.4-7.0 km s^{-1} and is ~6 km thick.

East Africa[33]. Gravity modelling using Woollard's[34] velocity-density relationships is consistent with a crustal thinning of 11-14 km between profile I and ESP 6 and a further thinning of ~14 km towards the trough axis. Both seismic refraction and gravity anomaly data require a high-velocity dense lower crust (heavy shading), which we believe corresponds to the highly reflective lower crustal layer.

The crustal thickness (20 km) deduced from backstripping data from well 419 (the nearest well to profile AB) is in general agreement with that deduced from the seismic and gravity data (18-19 km), suggesting that much, if not all, of the 6-km-thick lower crustal reflective layer was already in the crust before extension. If it was added later, say by underplating[25], then the thickness of the stretched crust would be reduced to 12-13 km which corresponds to $\beta = 2.4$-2.6. Thermal modelling shows that this value of β would yield a TTS of 2.5-2.7 km, which is not observed (Fig. 4). Another argument against underplating concerns the velocity of the lower crustal layer. As ESP 6 shows (Fig. 2), V_p is in the range 6.4-7.0 km s^{-1}, which is significantly smaller than the velocities of 7.2-7.4 km s^{-1} reported from rifted margins such as the Baltimore Canyon trough[35] and Hatton Bank[36] which are believed to have been underplated.

The model in Fig. 5 implies that the highly reflective lower crustal layer is 13-15 km thick beneath the western end of profile AB and is absent beneath the Valencia trough. This thickness is in agreement with seismic refraction results along profile I[22], although there is no evidence along this profile of the reflective nature of the lower crust. The nearest seismic reflection profile is the ECORS Pyrenees South line[37] (Fig. 1) which shows a 2-s TWT, or 6.5-km-thick layer (assuming a velocity of 6.6 km s^{-1}). The lower crust on this line has, however, been involved in the Pyrenean deformation. The western end of profile AB is located on Hercynian basement between the deformed zones of the Pyrenees and Betics. ECORS profiling of Hercynian crust in the Ardennes massif[16] shows that the reflective layer is typically 4-s TWT, or 13 km thick, in agreement with the thickness deduced at the western end of profile AB. If the 'normal' thickness of the lower crustal layer is 13 km, its absence beneath the trough suggests it has been either thinned by a greater amount than the upper crust or pervasively intruded by magmatic material so that the V_p of 7.8 km s^{-1} (Fig. 2) corresponds to some form of 'crust-mantle mix'.





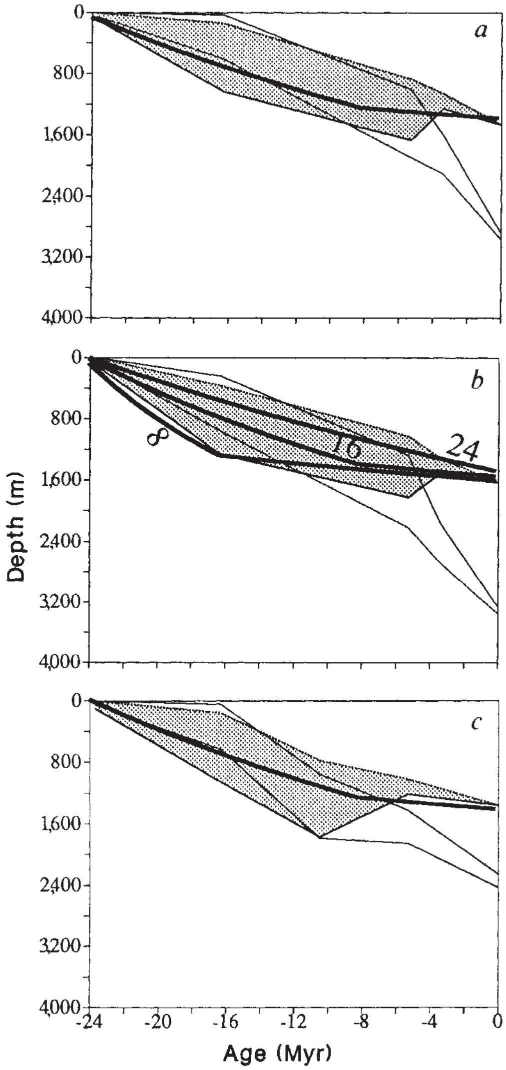


FIG. 4 Subsidence history of the flanks of the Valencia Trough based on backstripping stratigraphic data[15] from the Castellon Wells *a*, 299, *b*, 419 and *c*, 466. Tectonic subsidence (shaded area), sediment accumulation (thin solid line) and calculated subsidence curves (thick solid line) based on finite-rifting models[29,30] with rifting duration of 16 Myr and $\beta = 1.40$ (well 299), rifting duration of 16 Myr and $\beta = 1.45$ (well 466), and $\beta = 1.55$ and rifting durations of 8, 16 and 24 Myr (well 419).

Our data do not support the view that the highly reflective lower crustal layer beneath the flanks of the Valencia trough is the result of the mid-Tertiary extensional event that formed the trough, even though this event seems to have been a protracted one. Elsewhere in Europe, the reflective layer apparently 'ponds' Hercynian structures and it has been suggested[16] that they may post-date the Carboniferous. Moreover, the reflective layer is thinned on the ECORS Pyrenees South line[37] indicating a pre-Cretaceous age. Bois *et al.*[16] suggested that the reflective layer was formed by re-equilibriation of the crust following the Hercynian orogeny but, other data[8] support the view that they originated by a mechanical transformation of the crust during extension. Our data suggest that a highly reflective lower crustal layer was already in the Iberian crust before rifting. The Valencia Trough, however, has few tilted fault blocks[24], a relatively low level of magmatic activity[38], and did not generate oceanic crust, so we cannot rule out the possibility that a more widespread extensional event, such as that associated with the Tethys, did not cause the highly reflective lower crust of Iberia and, perhaps, the rest of Europe. □

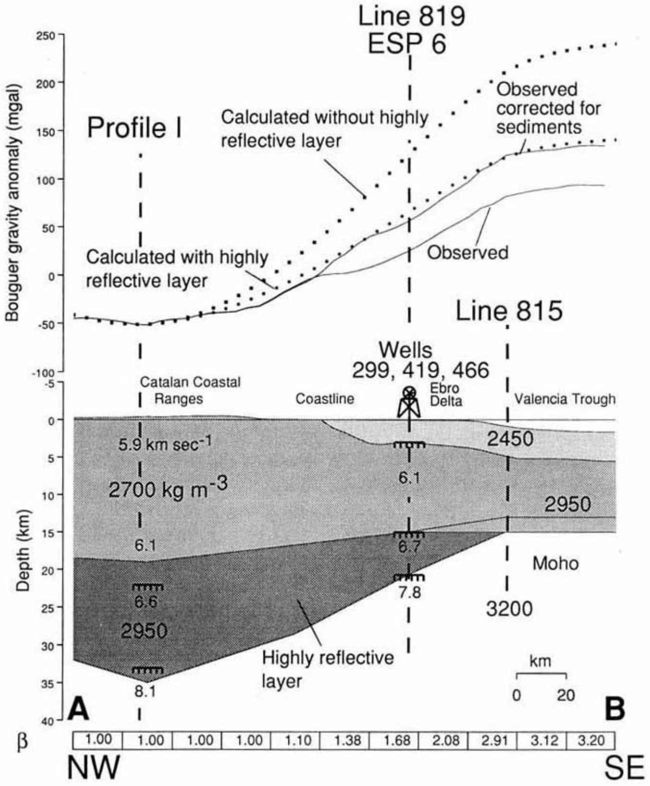


FIG 5 Comparison of the observed Bouguer gravity anomaly (A.B.W. and M.T., manuscript in preparation) on profile AB to calculated profiles based on the seismically constrained crustal structure at profile I and ESP 6. The heavy shading shows the dense highly reflective lower crustal layer which thins toward the axis of the trough and thickens beneath Iberia. The medium shading shows the acoustically transparent upper crust. The light shading shows the distribution of sediments. The stretching factor β is based on the seismically and gravimetrically constrained crustal model and an initial (unstretched) crustal thickness of 31.2 km.

Received 15 June; accepted 8 October 1990.

1. BIRPS & ECORS *J. geol. Soc. Lond.* **143,** 45-52 (1986).
2. DEKORP Research Group *J. Geophys.* **57,** 137-163 (1985).
3. DEKORP Research Group *Tectonophysics* **173,** 199-206 (1990).
4. Mathur, S. P. *Tectonophysics* **100,** 163-173 (1983).
5. Allmendinger, R., Hauge, T., Hausser, E., Potter, C. & Oliver, J. *Spec. Publ. geol. Soc. Lond.* **28,** 223-246 (1987).
6. Mathews D. H. & Cheadle M. in *Reflection Seismology Geodyn. Ser.* Vol. 13, 5-20 (American Geophysical Union, Washington, DC, 1986).
7. Reston, T. J. *Tectonics* **7,** 929-945 (1988).
8. Meissner, R. & Kusznir, N. J. *Ann. Geophys.* **B5,** 365-374 (1987).
9. Mathews, D. H. & BIRPS *Geophys. J. R. astr. Soc.* **89,** 209-215 (1987).
10. Julivert, M., Fontbote, J. M., Ribeiro, A. & Conde, L. N. *Memoria Explicativa del Mapa tectónico de la Peninsula Ibérica y Baleares* (Instituto Geologico y Minero de España, Madrid, 1972).
11. Mauffret, A. *Mém. Soc. géol. France* **132,** 1-96 (1977).
12. Banda, E., Ansorge, J., Boloix, M. & Cordoba, D. *Earth planet. Sci. Lett.* **49,** 219-230 (1980).
13. Torné, M. & Banda, E. *II Congreso Geológico de España* (Proc.) Vol. 2, 219-222 (Sociedad Geologica de España, Granada, 1988).
14. Stoffa, P. L. & Buhl, P. *J. geophys. Res.* **84,** 7645-7663 (1979).
15. *Contribution de la exploracion petrolifera al cononcimiento de la Geologia de España* (Instituto Geológico y Minero de España, Madrid, 1987).
16. Bois, C., Pinet, B. & Roure, F. in *Properties and Processes of Earth's Lower Crust* Vol. 6, 17-31 (Am. geophys. Un., Washington, DC, 1989).
17. Hobbs, R. W., Peddy, C. & BIRPS group *Geophys. J. R. astr. Soc.* **89,** 239-242 (1987).
18. Chadwick, R. A., Pharon, T. C. & Smith, N. J. P. *J. geol. Soc. Lond.* **146,** 617-630 (1989).
19. Marillier, F., Tomassino, A., Patriat, P. & Pinet, B. *Mar. Petrol. Geol.* **5,** 65-74 (1988).
20. Blundell, D. J. *The Potential of Deep Seismic Profiling for Hydrocarbon Exploration* (eds Pinet, B. & Bois. C.), 317-334 (Technip, Paris, 1990).
21. Mooney, W. D. & Brocher, T. M. *Geophys. J. R. astr. Soc.* **89,** 1-6 (1987).
22. Zeyen, H. J., Banda, E., Gallart, J. & Ansorge, J. *Earth planet. Sci. Lett.* **75,** 393-402 (1985).
23. Peddy, C. *et al. J. geol. Soc. Lond.* **146,** 427-437 (1989).
24. Torné, M. *et al. Terra Abstr.* **2,** 119 (1990).
25. Cox, K. G. *J. Petrol.* **21,** 621-650 (1980).
26. Watts, A. B. & Ryan W. F. *Tectonophysics* **36,** 25-44 (1976).
27. Sawyer, D. J. *J. geophys. Res.* **90,** 7751-7769 (1985).
28. McKenzie, D. P. *Earth planet. Sci. Lett.* **40,** 25-32 (1978).
29. Jarvis G. T. & McKenzie, D. P. *Earth planet. Sci. Lett.* **48,** 42-52 (1980).
30. Cochran, J. R. *Earth planet. Sci. Lett.* **66,** 289-302 (1983).

31. Hsu, K. I., Cita, M. B. & Ryan W. B. F. *Init. Rep. DSDP* Leg 42, 943–949 (1977).
32. Dañobeitia, Ju. J., Alonso, B. & Maldonado, A. *Mar. Geol.* (in the press).
33. Long, R. E. & Backhouse, R. W. *Geophys. J. R. astr. Soc.* **44,** 677–688 (1976).
34. Woollard, G. P. *Bur. Gravimetrique Int. Bull. d'Inform.* **36,** 106–110 (1975).
35. LASE study group. *Mar. Petrol Geol.* **3,** 234–242 (1986).
36. White, R. S. *et al. Geophys. J. R. astr. Soc.* **89,** 265–272 (1987).
37. ECORS Pyrenees Team *Nature* **331,** 508–511 (1988).
38. Marti, J., Grachev, A., Mitjavila, J., Aparicio, A. & Roca, E. *Terra Abstr.* **2,** 114 (1990).
39. *International Bathymetric Chart of the Mediterranean* (Intergovernmental Oceanographic Commission).
40. Stoffa, P. L., Diebold, J. B. & Buhl, P. *Geophys. Prosp.* **30,** 25–57 (1982).

ACKNOWLEDGEMENTS. This work was supported by the NSF.

Use of learned odours by a parasitic wasp in accordance with host and food needs

W. J. Lewis & Keiji Takasu*

Insect Biology & Population Management Research Laboratory,
US Department of Agriculture, Agricultural Research Service,
PO Box 748, Tifton, Georgia 31793, USA
* Visiting scientist with the Department of Entomology,
Coastal Plain Experiment Station, University of Georgia, Tifton,
Georgia 31793, USA, from the Division of Entomology,
National Institute of Agro-Environmental Sciences, Kannondai 3-1-1,
Tsukuba, Ibaraki 305, Japan

ADULT parasitic wasps need nectar or some other fragrant food source[1,2], but the effect of food odours on their behaviour has not been investigated to any extent[3]. Females of the parasitic wasp *Microplitis croceipes* learn volatile odours associated with host sites and use them to find hosts more effectively[4,5]. We have now performed flight tunnel experiments that show that this wasp also uses airborne odours to find food sources. Females learn associatively and subsequently fly to volatile odours presented for smell while they are feeding on sugar water. Furthermore, they can learn two novel odours associated with separate host and food resources and then make an accurate choice between these odours on the basis of their relative host and food needs. This ability of parasitic wasps to link different odours with specific resources and then effectively to use them as cues for choice between competing needs is of fundamental and applied importance.

Females of *M. croceipes* fed on wildflower honey subsequently flew up-wind to the odour of honey, whereas naive females and females fed a pure aqueous sucrose solution both responded much more weakly (Fig. 1). To determine whether this oriented response to food was learned, female wasps were provided with either one of two arbitrarily selected odours, vanilla or chocolate, while feeding on sucrose. A droplet of the vanilla extract or chocolate extract was placed near the sucrose solution so that the wasp could smell the odour while simultaneously tasting the sucrose, but was not allowed to taste or otherwise contact the odour. Females so trained showed a clear preference for the respective odour of their training when subsequently provided with a choice of these two odours in the flight chamber (Fig. 2). Females given the smell of vanilla or chocolate by the same procedure, but separately from feeding, did not respond to either odour.

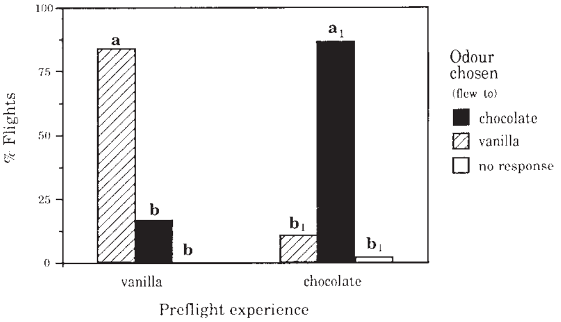


FIG. 2 Flight responses by *M. croceipes* females to vanilla or chocolate extract after smelling one of these odours while feeding on sugar water (preflight experience). Bars within the same treatment group capped by different letters are significantly different, $P<0.01$, Waller-Duncan K-ratio t-test; minimum significant difference, 14.3%, $n=64$ wasps (8 replications, 4 wasps per replication per preflight treatment).
METHODS. Females were reared and handled as described for Fig. 1. The two-day-old females were given a 10-μl droplet of sugar water (20% sucrose) as described for Fig. 1. In addition, however, a 10-μl droplet of either vanilla (Nielsen-Massey) or chocolate (McCormick) extract was placed 5 mm away from the sugar water for simultaneous smelling while feeding (care was taken that the females did not touch the extract). Wasps were permitted feeding/smelling training sessions of 5 s and sessions were repeated 5 times for each female with 2-min intervals between sessions. Twenty minutes after the final training session, females were released in the flight chamber as described in Fig. 1 and their response observed to a choice of vanilla extract (10 μl) or chocolate (10 μl) suspended 8 cm apart at the centre of the up-wind end of the chamber.

In earlier studies, females presented with odours in association with hosts and host frass likewise linked these odours to hosts and flew to the odours in search of host resources[4,5]. We conducted tests to determine whether females could learn and

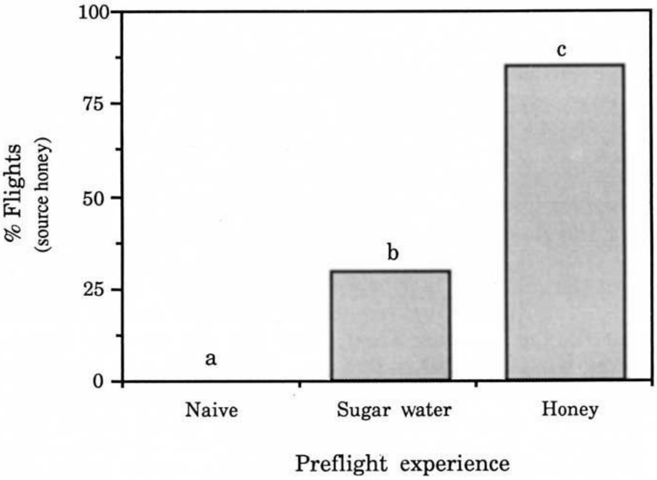


FIG. 1 Flight response of *M. croceipes* females to honey after no experience (naive), or feeding on sugar water or honey. Bars capped by different letters are significantly different, $P<0.01$, Waller-Duncan K-ratio t-test; minimum significant difference, 21.9%, $n=90$ wasps (5 replications, 6 wasps per replication per preflight treatment).
METHODS. *M. croceipes* were reared on larvae of *H. zea* fed an artificial diet. Females were allowed to mate and then held with a water supply in $30\times30\times20$ cm cages for 2 days after emergence. The 2-day-old females were each exposed to a drop of 20% sucrose water (10 μl) or honey (Powers, wildflower) (50 mg) placed on the bottom of a polystyrene Petri dish (8×1.5 cm). Females were allowed to walk directly from a vial onto the test material and then to feed on the material for 5 seconds. This experience was repeated 3 times with 2-min intervals. The wind tunnel has been described[4]. All flight responses were tested at 26–28 °C at a wind speed of 56 cm s^{-1} and at a light intensity of 2,000 lux. As an attractant source 50 mg of honey was pipetted onto a piece of Whatman number 1 filter paper suspended at the centre of the up-wind end of the tunnel. Females, tested individually, were released from a 4-dram shell vial 80 cm downwind and in the plume from the odour source. The behaviour of the females in the wind tunnel was observed until a complete flight occurred or 5 min had elapsed. A complete response involved the host-seeking flight behaviour described by Drost *et al.*[4] and included approach and landing on the odour source. For each observation, a female was given two chances to make a successful flight. Flight tests were conducted 20 min post-experience.