concentrate reported here results from the final step in Fahey's technique, which involves decanting a temporary suspensoid of fine-grained coesite after the coarser material has settled out (*6*). Thus, even with the acid-digestion method, a slightly different technique or a sample containing very fine-grained barite could result in a barite concentration. Since barite is a common secondary mineral in shear zones and breccia lenses, future workers should be aware of this problem. Barite is especially prevalent, for example, in the central United States, occurring in several well-known "cryptoexplosion" features (*8*). There are two possibilities: (i) barite may be mistaken for coesite; or (ii) the presence of barite (correctly identified) could make it difficult, if not impossible, to detect small amounts of coesite also present. The simplest way of avoiding these possibilities is to remove any barite present by treating the concentrate with hot sulfuric acid before attempting the coesite identification.

Note added in proof: C. Pomerol has subsequently supplied me with the complete x-ray data of Cailleux *et al.*; of the 28 reflections listed, virtually all are matched by barite or quartz reflections, or both.

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References and Notes

1. B. M. French and N. M. Short, Eds., *Shock Metamorphism of Natural Materials* (Mono, Baltimore, 1968).
2. A. Cailleux, A. Guillemaut, C. Pomerol, *C. R. Hebd. Séances Acad. Sci. Paris* **258**, 5488 (1964).
3. E. C. T. Chao, in *Researches in Geochemistry*, P. H. Abelson, Ed. (Wiley, New York, 1967), vol. 2, p. 204.
4. R. S. Dietz, R. F. Fudali, W. A. Cassidy, *Bull. Geol. Soc. Amer.* **80**, 1367 (1969).
5. Sample obtained from C. Pomerol; his specimen No. 13573.
6. J. J. Fahey, *Amer. Mineral.* **49**, 1643 (1964).
7. CuKα radiation; Ni filter; diameter of camera used to determine the x-ray powder pattern, 114.59 mm.
8. A. V. Heyl, *Econ. Geol.* **63**, 585 (1968).
9. F. Dachille and R. Roy, *Z. Kristallogr.* **111**, 451 (1959).
10. H. E. Swanson, R. K. Fuyat, G. M. Ugrinic, *Nat. Bur. Stand. (U.S.) Circ. 539* (1954), vol. 3.
11. I thank C. Pomerol for supplying the specimen for analytical work, R. S. Dietz for obtaining the specimen for me, and J. J. Fahey for his acid concentration of part of the sample.

6 June 1969; revised 10 July 1969

Macquarie Island and the Cause of Oceanic Linear Magnetic Anomalies

Abstract. *Macquarie Island is formed of probably Pliocene oceanic crust. Intruded into pillow lavas is a belt of harzburgite and layered gabbro masses cut by dike swarms. Similar belt-like structures may cause the linear magnetic anomalies of the oceans.*

Macquarie Island lies in the Southern Ocean on the seismically active Macquarie Ridge (Fig. 1), about 1100 km south-southwest of the southern tip of New Zealand. The island is about 39 km long and 3 km wide and is elongated north-northeast parallel to the ridge axis.

Mawson (*1*) divided the rocks of the island into three groups: an older basic group of lavas, in places intensely folded, intruded by the ultramafic and mafic plutonic rocks of the gabbroid group, with both groups overlain unconformably by a younger basic group of pillow lavas and agglomerates. Furthermore, Mawson considered that the island had been glaciated by an ice sheet which moved east-southeast from a gathering ground to the west of the island where there is now deep sea (*2*). It was probably the idea of a folded "basement" and the suggestion of a foundered land mass to the west of this isolated oceanic island that led Holmes (*3*) to refer to Macquarie Island as a "geological enigma" and a "critical area" for the study of ocean tectonics. Our reinterpretation (*4*) of the geology of part of Macquarie Island shows that it is composed entirely of oceanic crust material and gives an account of dilational features compatible with modern theories of ocean tectonics and crustal genesis.

In the northern third of the island (Fig. 2) the oldest rocks are a group of pillow lavas with interstitial *Globigerina* ooze and hyaloclastite, block lava, breccia, and minor graywacke. Within this group, which corresponds to Mawson's younger basic group, there are rapid changes between the various rock types, both along and across the strike. At Bauer Bay and Langdon Bay there is overturned pillow lava (Fig. 2); at Mawson Point and Brothers Point angular discordances occur, and thin graded graywacke beds are intercalated with the volcanic rocks. Faulting is common.

Paleontological evidence (*5*) shows that the *Globigerina* ooze in the interstices between the pillows is probably Pliocene in age and was deposited in 2000 to 4000 m of cold water. Lithological and structural features suggest a sporadic buildup of material on the sea floor by the extrusion of thick submarine lava flows, the deposition of brecciated volcanic material, and the mixing of lava with fragmental volcanic material and abyssal plain sediment.

Intruded into the extrusive rocks are ultramafic and mafic bodies (Mawson's gabbroid group) and dike swarms (Mawson's older basic group). These intrusive rocks form a clearly defined belt, 4 km wide, trending 330° (true) obliquely to the long axis of the island. The age limits of this intrusive belt are set by the probable Pliocene age of the extrusive rocks and by the age of the glaciation which affected the island (*6*).

Intrusive activity took place in three stages. The earliest intrusions are of harzburgite which now occur as wedge-shaped bodies up to 150 m wide, elongated in a northwest direction. That a tensional stress field prevailed during serpentinization of the harzburgite is indicated by a set of near-vertical closely spaced anastomosing cracks filled with cross-fiber asbestos and oriented parallel to the mean regional trend of the lithological striping of the intrusive belt.

Later intrusions of gabbro also occur principally as wedge-shaped slices up to 1 km wide elongated in a northwest direction, although smaller bodies are common as dilational dikes in the ultramafic rocks and as wedge-shaped or planar screens within the dike swarms. Rhythmic layering is well developed in the gabbros in the central portion of the intrusive belt.

Dolerite dikes, 1 to 3 m thick, were intruded in the last stages of igneous activity. They occur in swarms, commonly dense enough to exclude the country rocks. Two main types of dolerite are present, a coarsely feldsparphyric type and an aphyric type. The phenocrysts of the feldsparphyric dikes are concentrated in their central portions and form swirls around irregularities in the dike walls, thus showing that the phenocrysts were present when the magma was being intruded (*7*).

The margins of the intrusive belt are

comparatively sharp. Although pillow lava screens are, in places, preserved within the belt, the transition from predominantly extrusive rocks with few dikes to intrusive rocks with few screens occurs in about 50 m.

The intrusive activity appears to present a simple picture. Initially, the oceanic crust opened along a narrow tensional crack into which harzburgite was intruded. With continued dilation the gabbro was emplaced and cooled under tranquil conditions, thus allowing the layering to form. At this stage the intrusive belt was about 1.5 km wide (Fig. 2). Later the gabbro was pulled apart and intruded by swarms of dikes, until the intrusive belt attained its final width of 4 km.

We now present arguments that Macquarie Island represents part of the Pliocene oceanic crust. The island is located on the Macquarie Ridge (Fig. 1). Near the island the crest of the ridge is trenched, a feature which may imply faulting. The alignment of the long axis of the island parallel to the ridge axis, and the linearity of its east and west coasts, suggest that it is bounded by faults (*1*).

The association of pillow lava with interstitial *Globigerina* ooze, hyaloclastite, and graywacke is characteristic of ocean-floor deposition and occurred at depths between 2000 and 4000 m; the island has therefore been raised to its present position since the Pliocene, probably by faulting associated with tectonic activity along the Macquarie Ridge. Indeed, the island is probably still rising; beach deposits occur at 200 m and 100 m above sea level, and an extensive wave-cut platform fringes the west coast of the island at about 10 m above sea level.

It has been suggested that oceanic basalts may have distinctive chemical characteristics (*8*). Although more alkaline types occur (*9*), it still appears that olivine tholeiite is the most abundant oceanic basalt type, possessing olivine, diopside, and hypersthene in the norm, rich in Al_2O_3, poor in K_2O, and with a high ratio of Na_2O to K_2O. The basaltic rocks of Macquarie Island conform petrologically to these criteria (*10*), and their chemical compositions are similar to basalts of the mid-Atlantic Ridge (Table 1).

If Macquarie Island formed part of the Pliocene oceanic crust, then could the intrusive belt striking across the island be typical of the form taken by new oceanic crust material and, by inference, of the bodies which cause the linear magnetic anomalies of the ocean basins of the world? It has been proposed that the ocean floors spread apart at the mid-ocean ridges and that new crustal material is injected along the ridge axes (*11*). Much of the evidence in support of this proposal is geophysical and, as Gass (*12*) points out, several aspects require geological investigations of the sea floor. In particular, the nature of the new crustal material introduced along the ridge axes is unknown.

Table 1. Chemical composition in oxide percentages (by weight) of oceanic olivine tholeiite, based on the analysis of 40 samples from the mid-Atlantic ridge (*18*), for comparison with that of seven samples of similar basalts, dolerites, and gabbros from Macquarie Island (*1*).

Component	Mid-Atlantic Ridge		Macquarie Island	
	Mean	S.D.	Mean	S.D.
SiO_2	49.27	0.77	48.50	1.48
TiO_2	1.37	0.28	1.16	0.55
Al_2O_3	15.93	1.50	16.51	2.09
Fe_2O_3	2.19	0.73	2.12	1.01
FeO	7.12	1.30	5.52	1.44
MnO	0.16	0.03	0.12	0.06
MgO	10.47	13.15	8.93	3.55
CaO	11.31	0.95	11.62	1.34
Na_2O	2.70	.21	2.60	0.65
K_2O	0.27	.17	0.27	.13
H_2O+	.82	.62	1.87	.73
H_2O-	.45	.48	0.60	.41
P_2O_5	.15	.04	0.28	.10

Three recent solutions yield thrust and strike-slip components for earthquakes along the Macquarie Ridge, and it has been suggested that the ridge is not strictly comparable with the spreading type of mid-oceanic ridge (*13*). Yet it is certain that the intrusive belt of Macquarie Island is of tensional origin and that it therefore provides an example of the sequence of events during dilation of the oceanic crust. If the belt and ridge are related, a tensional environment may have developed between nested faults with substantial transcurrent components. Alternatively, the belt may be part of an older structure raised to the surface by faulting along the ridge and yet unrelated to it, since we here propose that any part of the oceanic crust away from the mid-oceanic ridges should bear the traces of sea-floor spreading in the form of this type of lithological striping.

In the mid-Atlantic, it seems that (*9, 14*) ultramafic intrusions are commonly exposed in the fracture and transverse fault zones of the ridge and are rarely exposed elsewhere. Muir and Tilley (*15*) show that "well-developed layered gabbro intrusions should occur at quite moderate depths below the basalts forming the crust of the (mid-Atlantic) rift." The only other volcanic complex known to be composed of ultramafic and mafic intrusions associated with dense dike swarms is the Troodos Massif of Cyprus, which Gass has termed a fragment of the Mesozoic mid-Tethyan rise (*12*).

Vine and Matthews (*16*) suggested that, as the ocean floor is pulled apart along the ridge axes, the new oceanic crust material entering the tensional

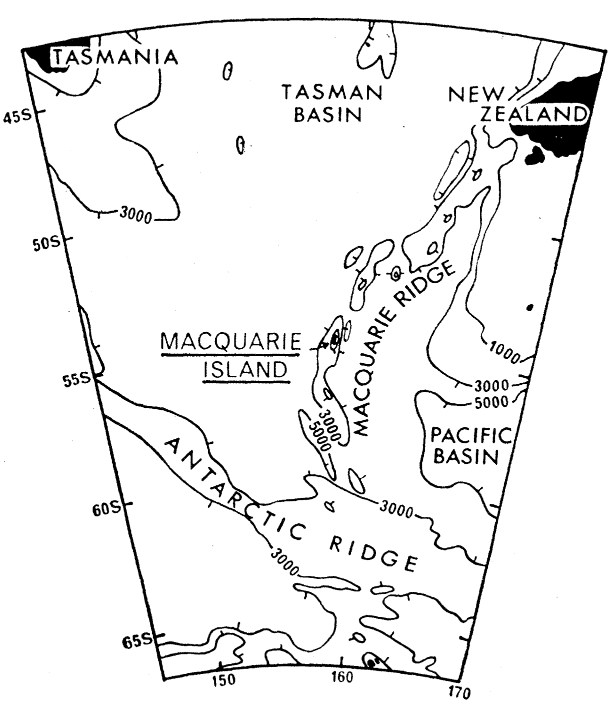

Fig. 1. Locality map showing major bathymetric features. Bathymetry sketched from J. W. Brodie and F. W. Dawson [*Nature* **207**, 844 (1965)]; map of Pacific Ocean (1:25 × 10^9 scale) [Glavnoe upravlenie geodezii i kartografii ministerstva geologii i okhany nedr SSSR, Moscow, 1963]; P. Lawrence, *N.Z. Oceanogr. Inst. Chart Misc. Ser. 15* (1967). Isobaths at 1000, 3000, and 5000 m.

crack is magnetized according to the polarity of the earth's field. As the ocean floors spread, geomagnetic field reversals produce bands of material exhibiting alternately normal and reverse magnetization; these bands cause the linear magnetic anomalies parallel to the ridges. Measured at the ocean surface, the anomalies are typically tens of kilometers wide, but a different pattern of anomalies appears when observations of the magnetic field are made close to the ocean floor (*17*). These anomalies are more numerous and are of higher amplitude and smaller width.

Although detailed investigations are necessary to evaluate this proposal, we conclude that the intrusive belt of Macquarie Island, with its tensional pattern of interleaved ultramafic and layered gabbro masses cut by dike swarms, fits the known geophysical, tectonic, and petrological features of the material injected along the mid-oceanic ridge axes and of the bodies which cause the linear magnetic anomalies of the ocean basins.

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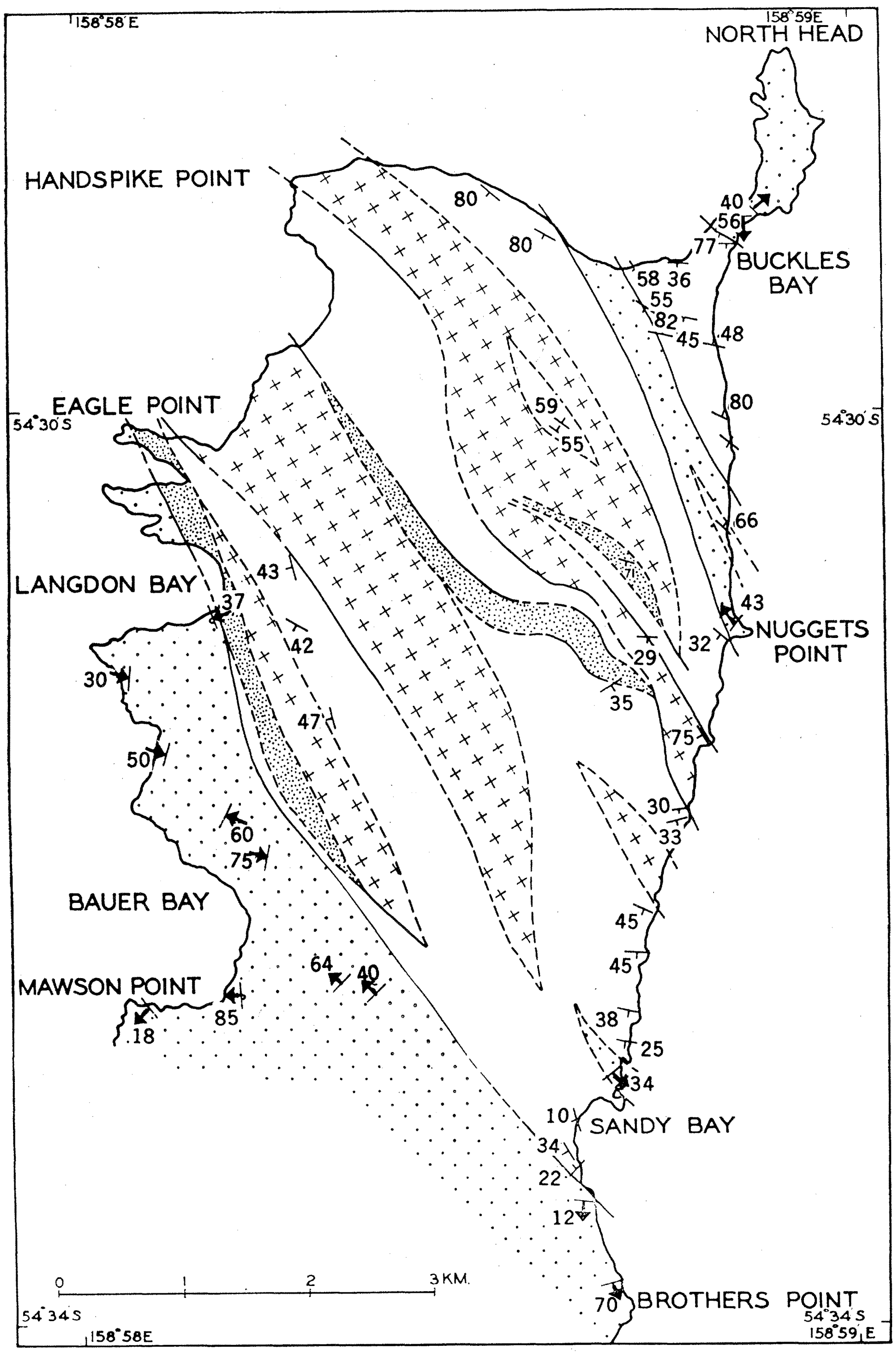

Fig. 2. Geological map of the northern part of Macquarie Island. Coarse stippling, older extrusive rocks, mainly pillow lava with interstitial *Globigerina* ooze, with some hyaloclastite, breccia, and graywacke; fine stippling, ultramafic rocks; crosses, gabbro; blank space, dike swarms; strikes with arrows, bedding in pillow lava; strikes with bars, attitude of dikes; broken lines indicate concealed contacts beneath superficial glacial deposits.

References and Notes

1. D. Mawson, *Australian Antarctic Expedition 1911–1914 Scientific Reports* (Government Printing Office, Sydney, Australia, 1943), series A, vol. 5. This report was based mainly on the records of L. R. Blake, a surveyor.
2. Although the island has been glaciated, the concepts of an overriding ice sheet and, with it, of a foundered land mass to the west of Macquarie Island, must be abandoned. They arose mainly because Blake (*1*) mistook a line of harzburgite outcrops as a train of ice-dumped boulders derived from a harzburgite outcrop on the west coast.
3. A. Holmes, *Principles of Physical Geology* (Nelson, Camden, N.J., ed. 2, 1965), p. 933.
4. Our reconnaissance survey was carried out in December 1968, during the resupply of the Australian National Antarctic Research Expeditions' station on the island; we thank ANARE for making this study possible.
5. F. Chapman [in Mawson (*1*)] recorded the presence of foraminifera and radiolaria in the *Globigerina* ooze and suggested that it probably accumulated at a depth between 2000 and 4000 m. Pteropods are also present. The limited variety of planktonic foraminifera and the absence of keeled forms suggest a cold-water fauna. *Globigerina pachyderma* (Ehrenberg) (probably *G. dutertrei* of Chapman) is the dominant species; although it ranges from the Upper Miocene to Recent in age, it was not abundant until the Pliocene, and the ooze is therefore probably Pliocene or younger.
6. Glaciation in the Antarctic began at least 5×10^6 years ago, according to H. G. Goodell and N. D. Watkins [*Deep-Sea Res.* **15**, 89 (1968)], but other workers set the Pliocene-Pleistocene boundary at about 2×10^6 years ago, with four major glaciations in the Pleistocene [D. B. Ericson and G. Wollin, *Science* **162**, 1227 (1968)]. The glaciation of Macquarie Island is thus difficult to date.
7. Reversals in the dip of the dikes have been interpreted as the result of folding (*1*). They are due, however, to a dike distribution about a near-horizontal axis trending 300°, probably the intermediate stress axis. Most of the dikes dip at about 50° southwest, a departure from the near-vertical attitude to be expected of extension fractures formed at the surface; this may indicate a depth of intrusion of 2 or 3 km.
8. A. E. J. Engel, C. G. Engel, R. G. Havens, *Bull. Geol. Soc. Amer.* **76**, 719 (1965).
9. W. G. Melson, G. Thompson, T. H. van Andel, *J. Geophys. Res.* **73**, 5925 (1968).
10. The extrusive rocks of the island are mainly megaphyric and aphyric tholeiitic bytownite-basalt with lesser amounts of glassy tholeiitic and rare alkaline basalt. The dolerites are also predominantly tholeiitic in character, and the gabbroic rocks include olivine gabbro, troctolite, eucrite, olivine eucrite, allivalite, and harrisite varieties. The ultramafic rocks are serpentinized harzburgite with minor dunite (*1*).
11. H. H. Hess, in *Petrologic Studies: A Volume to Honor A. F. Buddington* (Geological Society of America, Boulder, Colorado, 1962), p. 5 → R. S. Dietz, *Nature* **190**, 854 (1961).
12. I. G. Gass, *Nature* **220**, 39 (1968).
13. L. R. Sykes, *J. Geophys. Res.* **72**, 2131 (1967); A. R. Banghar and L. R. Sykes, *ibid.* **74**, 632 (1969). The computation of X. Le Pichon [*J. Geophys. Res.* **73**, 3661

(1968)] indicates, however, a small amount of expansion across the Macquarie Ridge near Macquarie Island.
14. J. R. Cann and B. M. Funnel, *Nature* **213**, 661 (1967).
15. I. D. Muir and C. E. Tilley, *J. Petrol.* **5**, 409 (1964).
16. F J. Vine and D. H. Matthews, *Nature* **199**, 854 (1963).
17. B. P. Luyendyk, J. D. Mudie, C. G. A. Harrison, *J. Geophys. Res.* **73**, 5951 (1968).
18. The 40 analyses of tholeiites from the mid-Atlantic ridge containing olivine, diopside, and hypersthene in the norm were drawn from the following: Engel *et al.* (8), five analyses; Melson *et al.* (9), four analyses; Muir and Tilley (15), eight analyses; I. D. Muir and C. E. Tilley [*J. Petrol.* **7**, 193 (1966)], ten analyses; F. Aumento [*Can. J. Earth Sci.* **5**, 1 (1968)], seven analyses; G. D. Nicholls [*Mineral. Mag.* **34**, 373 (1965)], four analyses; A. Poldervaart and J. Green [*Amer. Mineral.* **50**, 1723 (1965)], two analyses. If more than one analysis was made of the same rock, these analyses were first averaged. The seven analyses of Macquarie Island basalts, dolerites, and gabbros containing olivine, diopside, and hypersthene in the norm are from Mawson (1).

13 May 1969; revised 24 June 1969

Androgen Accumulation and Binding to Macromolecules in Seminal Vesicles: Inhibition by Cyproterone

Abstract. *Cyproterone reduces the accumulation of testosterone and dihydrotestosterone in seminal vesicles 30 minutes after intravenous administration of tritiated testosterone to castrated rats. Testosterone, added in vitro, binds to macromolecules from the supernatant fraction of the seminal vesicle homogenates; this interaction is antagonized competitively by cyproterone. Cyproterone may diminish androgenic effects by competition for binding molecules.*

Cyproterone is an experimental steroid (*1*) which antagonizes the effects of androgens in both central and peripheral tissues involved in reproduction. Cyproterone reduced the increase in the weight of the seminal vesicle, prostate, and testis induced by testosterone in hypophysectomized rats (*2*). This inhibition was classified as competitive because the cyproterone effect was greater with lower doses of testosterone (*2*). Androgen secretion by the testis is thought to be responsible for most aspects of sexual differentiation during fetal and early neonatal life (*3*). Cyproterone treatment of rats during pregnancy resulted in male (XY) offspring with a vagina and nipples and the potential for mammary gland enlargement (*4*). The vagina in these males was retained in adulthood and was responsive to estrogen if cyproterone treatment was continued during the first 3 weeks after birth (*5*). Feminization of the hypothalamic regulation of gonadotrophin secretion occurred as well; males exposed to cyproterone as fetuses and newborns can potentially ovulate as evidenced by the development of corpora lutea in transplanted ovaries (*6*). Cyproterone implanted in the basal hypothalamus of intact, sexually mature male rats resulted in hypertrophy of the seminal vesicles, prostates, and testes; apparently, cyproterone blocked feedback inhibition by testosterone of gonadotrophin secretion, leading to increased testosterone amounts (*7*). Cyproterone may compete with testosterone for receptor sites in target tissues. By in vivo and in vitro techniques our findings provide evidence consistent with such a mechanism.

We studied the effects of cyproterone on the accumulation of ^{3}H-testosterone and its metabolites in the seminal vesicle in vivo. After ^{3}H-testosterone is systemically administered, radioactivity is accumulated selectively in both the seminal vesicle and prostate (*8, 9*). Furthermore, testosterone is rapidly converted in the prostate to a metabolite that has been identified as dihydrotestosterone (5-α-androstan-17-β-ol-3-one) (*10*).

Adult male Sprague-Dawley rats castrated 3 weeks previously were injected intravenously with 0.1 μg of ^{3}H-testosterone (*11*) in aqueous solution per 100 g of body weight. Five minutes before they received the radioactive testosterone, seven experimental males were injected intravenously with cyproterone (1 mg per 100 g of body weight); seven control males received the ethanol vehicle alone. One-half hour later, the tissues were removed, weighed, and rapidly frozen. The tissue was homogenized in 10 ml of acetone, with ^{14}C-testosterone and ^{14}C-androstenedione added to monitor recovery. After 15 to 24 hours at 4°C, the homogenate was filtered, concentrated under a nitrogen stream to about 1 ml, and partitioned twice between 10 ml of ether and 5 ml of H_2O to remove conjugates. After the ether phase was dried, the sample was dissolved in 0.05 ml of methanol, with nonradioactive testosterone and androstenedione added as carriers, for chromatography. The descending chromatographic system consisted of Whatman No. 1 paper impregnated with a mixture of methanol and propylene glycol (60 : 40) as stationary phase and ligroin (b.p. 60° to 90°C) as mobile phase (*12*). Testosterone moves 5 cm from the origin during 24 hours; the mobility of other androgens relative to testosterone in this system is: etiocholanolone, 2.4; dihydrotestosterone, 3.0; androsterone, 4.1; and androstenedione, 5.0. Reference steroids were localized by ultraviolet absorption and the Zimmerman reaction (*12*). The chromatographic strip was cut into small segments, and radioactivity was determined in a liquid-scintillation counter set for dual isotope counting. The values are corrected for interference in the ^{3}H-channel by ^{14}C, for counter efficiency, and for recovery of the ^{14}C tracer. Further characterization of the identity of the radioactivity in the testosterone and dihydrotestosterone zones was obtained by rechromatography and crystallization to constant specific activity.

Higher concentrations of testosterone and dihydrotestosterone were found in the seminal vesicle than in plasma (Fig. 1). One-half hour after intravenous administration of radioactive testosterone, the concentrations of testosterone and dihydrotestosterone in the seminal vesicles were 3 and 80 times greater, respectively, than those in the plasma. In the seminal vesicle the radioactivity was distributed as 27 percent testosterone, 63 percent dihydrotestosterone, and less than 2 percent androstenedione, the remainder being primarily metabolites more polar than testosterone. Cyproterone reduced the radioactive testosterone and dihydrotestosterone in the seminal vesicle to 20 and 15 percent, respectively, of that in the control concentrations (Fig. 1). The ratio of testosterone to dihydrotestosterone was not significantly different in the control and cyproterone groups ($F = 0.04$; d.f. = 1.12). Concentrations of testosterone and dihydrotestosterone in plasma were unchanged by cyproterone treatment.

Our experiments in vitro indicate that cyproterone may compete with androgens for macromolecules from the seminal vesicle. The seminal vesicles and hearts from ten mature male Sprague-Dawley rats castrated 3 weeks previously were homogenized in 12 volumes of 0.01M tris(hydroxymethyl)aminomethane-hydrochloride, pH 7.4, containing 0.0015M ethylenediaminetetraacetate.