tests and the relative potency of its combination with DDT. This compound, which has been advanced as a miticide under the name *p,p'*-dichlorodiphenyl methyl carbinol (DMC), is the active ingredient of the proprietary product "Dimite" (*8*). The potency of DMC, coupled with its availability, prompted additional tests. The carbinol was mixed with DDT in varying proportions and tested under the conditions described above. The results are shown in Table 2.

TABLE 2

TWENTY-FOUR HOUR MORTALITY OF WILD FEMALE DDT-RESISTANT HOUSEFLIES FOLLOWING A 2-HR EXPOSURE TO DDT-DMC DEPOSITS ON A PAPER BOARD SURFACE

Test No.	Toxicant	Concentration (mg/sq ft)	Average mortality (%)	Replications
1	DDT	200	6	9*
2	DDT DMC	200 2	15	3
3	DDT DMC	200 20	78	7†
4	DDT DMC	200 25	73	2
5	DDT DMC	200 40	87	2
6	DDT DMC	200 100	83	2
7	DDT DMC	200 200	76	5‡
8	DDT DMC	20 200	2	3
9	DMC	200	0	3

* Replications made over a period of 25 days.
† " " " " " " 21 " .
‡ " " " " " " 4 " .

The synergistic effect of DMC on DDT was evidenced at the dosage level of 1 part DMC to 100 parts DDT. Very high kills were obtained from a combination of 100 parts DDT and 10 parts DMC, but the latter mortality rates were not raised appreciably by increasing further the proportion of DMC up to 50% of the mixture. Very low kills of houseflies were obtained from a deposit composed of 100 parts DMC and 10 parts DDT, the same dosage level at which the reverse combination is quite toxic. DMC alone gave no mortality among female houseflies.

The enhanced activity of the DDT-DMC combination is further pointed up by the fact that the following combinations were highly toxic to DDT-resistant flies: (*a*) DDT with 1,1-bis(*p*-fluorophenyl)-ethanol; (*b*) 2,2-bis(*p*-fluorophenyl)-1,1,1-trichloroethane with DMC; and (*c*) 2,2-bis(*p*-fluorophenyl)-1,1,1-trichloroethane with 1,1-bis(*p*-fluorophenyl)-ethanol. The last combination was the most effective of the three.

In preliminary field tests, a residual application of 200 mg DDT and 40 mg DMC failed to give lasting results against a highly resistant strain of flies at a dairy near Savannah. However, in limited field tests of outdoor mist space sprays against the same highly resistant houseflies, a water emulsion of 5% DDT and 1% DMC has given results approaching those originally obtained with DDT against nonresistant flies.

Preliminary experiments indicate that some DDT-DMC combinations may be more toxic to white rats on an acute oral basis than either compound alone. The breadth and mechanism of the synergistic effects of DMC on DDT in both insects and mammals are under investigation in both the laboratory and the field.

References

1. RANGANATHAN, S. K., *et al. Nature,* **164**, 1095 (1949).
2. RIEMSCHNEIDER, R. *Z. angew. Entomol.,* **31**, 431 (1949).
3. LYNN, G. E., *et al.* U. S. Patent 2,491,414 (Dec. 13, 1949).
4. STEWART, W. D., *et al.* U. S. Patent Appl. 707,526, *Official Gaz. U. S. Pat. Office,* **625**, 840 (1949).
5. MEDLER, J. T., *et al. J. Agr. Research,* **78**, 641 (1949).
6. PERRY, A. S., and HOSKINS, W. M. *Science,* **111**, 600 (1950).
7. SIMMONS, S. W., *et al. Public Health Repts. Suppl.,* **186**, 8 (1945).
8. GRUMMITT, O. *Science,* **111**, 361 (1950).

Submarine Canyons: A Joint Product of Rivers and Submarine Processes[1]

Francis P. Shepard

The Scripps Institution of Oceanography,
La Jolla, California

The abandoned sea-level-lowering hypothesis. This note is written in the hope that the writer will not continue indefinitely to be tied to the now long-discarded hypothesis that submarine canyons are the result of a lowering of sea level amounting to several thousand feet, which was thought to result from the formation of huge ice caps. This hypothesis was offered as a somewhat forlorn hope that seemed, at the time, to be the only way out of an enigma. Discoveries of the past few years have indicated that no such great lowering took place during the Pleistocene. The large submergences indicated by a considerable series of oceanographic discoveries appear to be more remote in age and to have, therefore, no relation to glacial control. Despite recent articles (*1*) and talks given before scientific societies during the past two years it has proved most difficult to bury the old hypothesis. In offering an alternative explanation with little amplification it should be noted that a much longer article is being prepared. This will give a complete account of the basis for suggesting still another origin for the much-abused submarine canyons.

A new composite hypothesis. New oceanographic information can now be combined with information from drill cores along the coasts and on islands to build a composite hypothesis that accounts for submarine canyons without appealing either to enormous movements of land or of sea level or to the excavation by powerful submarine currents for which there is no

[1] Contribution from the Scripps Institution of Oceanography, New Series No. 524.

evidence. It now appears that many of the canyons have three divisions as follows:

1. Inner valley heads that extend into shallow water along many coasts and contain indications of having been cut at a relatively recent period.

2. Intermediate canyons that have rocky walls rising hundreds or even thousands of feet above their narrow, winding floors.

3. Outer valleys, only slightly incised into great masses of unconsolidated sediment, which can be traced out to the base of the oceanic slopes.

These three divisions are not clearly separated one from the other and apparently have had a composite and overlapping origin. The outer two divisions can be explained by a sequence of events that fits into a pattern well known to geologists who have investigated the history of depositional basins (geosynclines). The submergence of a geosyncline is known to alternate with reversals of movement. Similarly, the deep submergence of the continental margins, which is thoroughly established from well records along many of the present coasts, was probably interspersed with stages of uplift or preceded by an uplift. During uplifts, the exposed continental margin was trenched by stream erosion, thus forming the intermediate canyons. Outside these canyons deltas developed on the lower oceanic slopes.

Following the cutting of the canyons, the slopes were submerged. The canyons became a locus of intensive deposition, but wherever they had high gradients the sediment was carried outward by submarine landslides such as are now well established as occurring in the canyons along the California coast. The soft sediments of the deltas are thought also to have undergone mass sliding movements, opening up cracks and scars on the delta fronts. One of the results of the slides was the development of turbidity (density) currents which transported the sediments down the canyon floors (*2*) and, moving across the deformed deltas, sank into the landslide scars and cracks, gradually transforming them into valleylike features. These "valleys" were eventually extended to the base of the continental slopes.

As submergence continued, deposits were formed in many places on the old surfaces into which the canyons had been cut. These deposits built up shelves such as those on the east coast of the U. S., but failed to eliminate the canyons because of the continuing landslides. Slides probably also took place on the continental slopes. In this way the canyons have walls that have grown upward as a result of deposition as the canyon floor sank.

During the glacial period, which lasted approximately one million years, the canyon heads were alternately exposed and submerged as the result of changing sea levels. During each glacial stage of lowered sea level the streams from the land have tended to flow into the heads of the canyons and have extended these heads farther in toward the present coasts. It is probably this stream erosion during glacial stages that accounts for the fresh appearance of canyon heads in shallow water (*3*).

The history of canyon development has been different in different areas. For example, in some regions, such as in Monterey Bay, California, the middle zone of the canyons extends far deeper than in most other areas, and the movements of both uplift and sinking appear to have been much greater. The upbuilding of the shelf during submergence has been very great along the northeast and Gulf coasts of the United States, but south of Cape Hatteras the shelf has apparently not been covered with sediment as it sank, with the result that the deep Blake Plateau represents a submerged shelf swept clean by bottom currents.

Evidence for the new hypothesis. The sequence of events described here is not a purely philosophical concept built up to explain a very puzzling situation, as some of the preceding hypotheses have been; it is built on a substantial and rapidly growing foundation of facts from marine investigations and from drill core loggings. A brief summary of the evidence, which will appear in full later, follows.

1. The inner canyons, where studied in detail (off La Jolla, off Carmel, and off the French Riviera), have an extraordinary resemblance to adjacent stream-cut canyons; that is, they have winding courses, branching tributaries, rock gorges with precipitous walls, and even terraces on the side.

2. There are many lines of evidence to support the contention of great submergence along the continental borders and in oceanic island masses. Deep wells along some of the coasts of the continents show that shallow water, or even terrestrial deposits, extend for thousands of feet below present sea level. Wells that significantly bear out these contentions have been drilled on Cape Hatteras and the Mississippi delta, the two points in the U. S. where deposition has extended the land out across the greater part of the continental shelf. Numerous other wells along the east and south coasts of the U. S. add confirmation, as do some well records of coastal California. Similar results come from wells drilled into oceanic islands, like Bikini (*4*). Rounded cobbles, indicative of wave action in shallow water, are found widespread on the banks and seamounts outside the continental slopes. Fossil evidence reported by R. S. Dietz, Maurice Ewing, and most recently by Roger Revelle indicates that these banks were covered only with shallow water at a time that probably preceded the ice age by many millions of years.

3. Channels similar to those found on steep delta fronts are found outside the rock canyons along the southern California coast, and these channels extend down the sides of bulging masses indicative of ancient deformed deltas.

4. There is no present evidence that either slumping or mud-laden currents are capable of excavating great rock-walled canyons like those on the sea floor. In fact, the steep fronts of deltas built into lakes in the Alps are known to be building out rather than having canyons cut into them.

5. The slight depressions in the fronts of lake deltas probably represent localities where currents or slides

have locally slowed the forward advance of the delta. These channels have little in common with the rock gorge type of submarine canyons but resemble the outer shallow valleys that form an extension of the submarine canyons.

6. Virtually all the arguments now being used for subaerial origin are based on the hypothesis of great lowering of sea level during the ice ages, an idea that was abandoned more than two years ago.

References

1. SHEPARD, F. P. *Bull. Geol. Soc. Am.*, **60**, 1597 (1949).
2. ———. *World Oil*, **132**, 61 (1951).
3. ———. *Bull. Geol. Soc. Am.*, **60**, 1597 (1949).
4. LADD, H. S., TRACEY, J. I., and LILL, G. G. *Science*, **107**, 51 (1948).

Maleic Hydrazide as an Antiauxin in Plants[1]

A. C. Leopold and W. H. Klein

Horticulture Department,
Purdue University, Lafayette, Indiana

In the first report of the action of maleic hydrazide on plants, Schoene and Hoffmann (*1*) demonstrated that this compound inhibited stem elongation and overcame the normal apical dominance in tomato plants. The same responses have subsequently been observed in many other plant species.

Growth inhibitors in general do not cause lateral buds to develop. However, one agent that does inhibit stem elongation and that breaks apical dominance is x-irradiation (*2*), and, interestingly enough, x-irradiation also causes the destruction of indoleacetic acid or auxin (*3*). Auxin is essential for growth and is apparently the controlling factor in apical dominance. The possibility suggests itself, then, that maleic hydrazide may act within the plant in opposition to auxin, i.e., as an antiauxin.

If maleic hydrazide does act as an antiauxin, it would be logical to expect it to inhibit growth where auxin is limiting, and that this inhibition should disappear when auxin is not limiting. This has indeed been found to be the case.

Using the standard slit pea test (*4*), initially inhibitory levels of maleic hydrazide were added to serial concentrations of auxin. The results were collected using the stem-reference technique of Thimann and Schneider (*5*). In typical data from such an experiment (Table 1) two salient features can be seen: (1) Maleic hydrazide at both the concentrations used (3 and 10 mg/l) inhibits growth in the presence of low concentrations of auxin (.01 and 0.1 mg/l indoleacetic acid). For example, referring to Table 1, maleic hydrazide inhibition in 0.1 mg/l auxin amounts to −118° and −126°, respectively, for the two inhibitor concentrations. These differences are both significant at the 1% level. (2) Maleic hydrazide at these same concentrations does *not* inhibit growth in the presence of high concentrations of auxin (10 and 100 mg/l indoleacetic acid). Thus the differences between the auxin controls and the maleic hydrazide treatments amount to +9 and −9°, −7° and +17°, respectively, for the two inhibitor concentrations. These differences do not approach significant levels.

TABLE 1

INHIBITION OF GROWTH BY MALEIC HYDRAZIDE AND ITS REVERSAL WITH HIGH CONCENTRATIONS OF INDOLEACETIC ACID
(Slit pea test, 17 hr; readings made by stem-reference method.)

IAA conc (mg/l)	Curvature without MH (degrees)	Curvature with 3 mg/l MH (degrees)	Difference due to added MH (degrees)	Curvature with 10 mg/l MH (degrees)	Difference due to added MH (degrees)
None	−227	−239	−12	−242	−15
.01	−135	−168	−33	−231	−96*
0.1	−13	−131	−118†	−139	−126†
1.0	162	152	−10	122	−40
10	337	346	9	330	−7
100	−125	−134	−9	−108	17

* LSD at 5% level: 76°.
† LSD at 1% level: 101°.

The capacity of auxin to overcome maleic hydrazide inhibition completely is reproducible over a wide range of concentrations of the inhibitor, and has been confirmed using two other growth tests: the pea straight growth test and the *Avena* straight growth test. Indoleacetic acid is not the only growth regulator capable of relieving maleic hydrazide inhibition. The same effect has been observed using naphthaleneacetic acid as the growth regulator.

Maleic hydrazide inhibition is not evident in the data in Table 1 in the treatment using no auxin. In the tests we have carried out it has been generally true that where conditions did not permit much growth maleic hydrazide inhibition was greatly reduced. In cases where growth is more active, however, maleic hydrazide inhibition is much more severe. This can be seen readily from Table 1 in the treatments using 0.01–0.1 mg/l of auxin.

The ability of maleic hydrazide to act as an antiauxin will be discussed in more detail in another paper (*6*). It is clear, however, that maleic hydrazide inhibition can be overcome by the addition of excess auxin, and hence it may properly be called an antiauxin.

Several other compounds capable of antagonizing auxin action have been described. Triiodobenzoic acid (*7*), unsaturated lactones such as coumarin (*8*), and 2,4-dichloroanisole (*9*) all have been demonstrated to antagonize auxin action. However, they have not been shown to be counteracted by the addition of more auxin, and work in our laboratory has failed to demonstrate such a characteristic in the first two of these. Hence it would seem that they act in a different manner than does maleic hydrazide.

One other antiauxin has been described which is

[1] Journal Paper No. 513, Purdue University Agricultural Experiment Station, Lafayette, Ind.