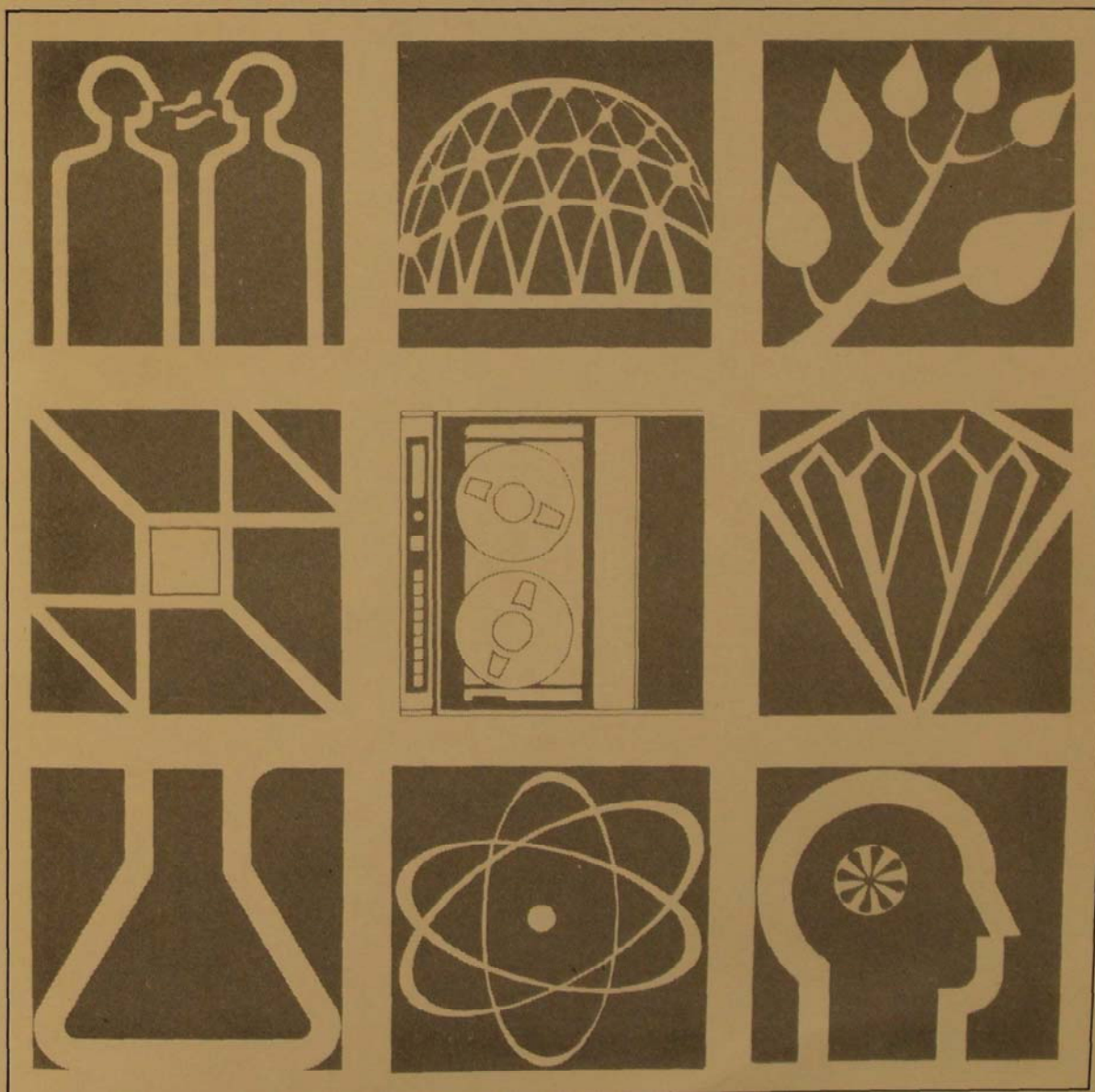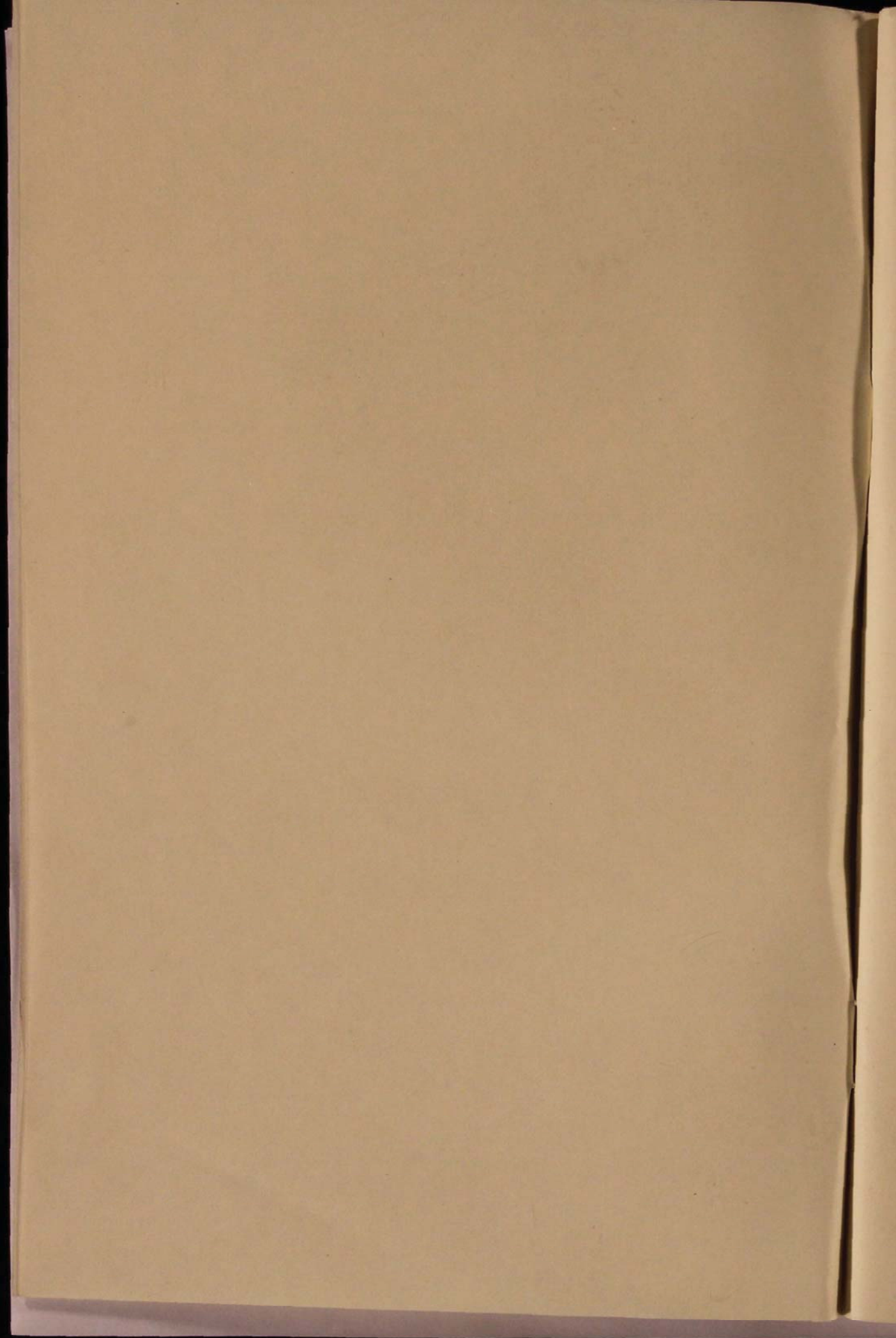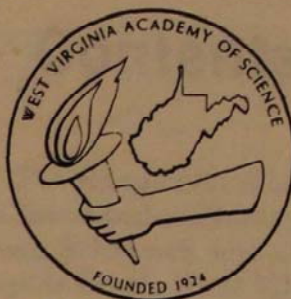# Proceedings
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Biology

Section

The Range and Distribution of the Cheat Mountain Salamander, *Plethodon nettingi*

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Abstract

The Cheat Mountain salamander, *Plethodon nettingi*, is a small eastern *Plethodon* that is found in the Allegheny Mountains of West Virginia.

Field surveys were conducted during 1976-81 to determine the total range, the vertical distribution, the number of populations, and the approximate number of individuals per population.

It was found that the total range is 18.7 x 50 miles (30 x 80 km) and, with one exception, the vertical distribution of a single population does not extend beyond 220 ft. (67 m). The lowest elevation in which the species occurs is 3450 ft. (1052 m) near Bear Haven, Randolph County; and the highest is 4500 ft. (1372 m) near Spruce Knob, Pendleton County. Of 181 sites surveyed, *P. nettingi* occurred in only 27. The number of individuals observed per site varied from 1 to 90.

Introduction

Plethodon nettingi is a small, slender salamander reaching a maximum length of 11.1 cm (Conant, 1975) and having a modal number of 18 costal grooves (Highton, 1971). The dorsal color is black, usually with brassy or white flecks. The venter is uniformly dark gray with a paler throat.

This salamander was first observed in 1935 on Barton Knob, Randolph County, West Virginia (Green, 1938). In 1938, Dr. N. Bayard Green described the species and named it after M. Graham Netting for his contributions to West Virginia herpetology. In 1956, Highton and Grobman suggested that the Cheat Mountain salamander be considered

a subspecies of *Plethodon richmondi*, the ravine salamander, thus changing the name to *Plethodon richmondi nettingi*. In 1971, Highton recommended that the Cheat Mountain salamander again be given full species status as *Plethodon nettingi*.

Brooks (1948) described the range of *P. nettingi* as an area extending from the headwaters of Condon Run, Randolph County, south to Thorny Flat, Pocahontas County. Highton (1971) found that the northern area of the *P. nettingi* range that Brooks had defined extended eastward to the high elevations of the Allegheny Front.

Because of its limited range in mountain areas, this species has received a great deal of attention from biologists. This report addresses the total range and distribution and the vertical range and distribution, as well as the number and approximate size of the populations.

Methods and Materials

Through preliminary field surveys and discussions with other biologists, it was determined that the *P. nettingi* vertical range did not extend below 3000 ft. (915 m). Therefore, elevation was the only criterion considered in selecting the 181 sites surveyed; vegetation, aspect, and location were not deemed important.

These sites were located on 19 mountains within the Monongahela National Forest. All sites were surveyed for at least one man-hour between 10 a.m. and 5 p.m. and usually within 48 hours of a rainfall. The observations occurred during the months of May through October of 1976 to 1981.

Results and Discussion

During the course of this study, 3710 salamanders (9 species) were observed in 167 of the 181 sites. A total of 537 *P. nettingi* was found in 27 sites on nine of the 19 mountains, and 778 individuals of various other species were found in these same 27 sites. The total range of *P. nettingi* was determined to be an area of 18.7 x 50 miles (30 x 80 km), extending east from McGowan Mountain through Mozark Mountain to Dolly Sods, south through Roaring Plains to Spruce Knob, southwest to Thorny Flat,* and north through Barton Knob to McGowan Mountain (Figure 1). This is the only *Plethodon* species known to occur totally within the borders of West Virginia.

The number of *P. nettingi* observed per site varied from 1 to 90. Fewer than 10 individuals were observed in 17 of the 27 sites, and none of these 27 populations are contiguous. Even those populations in close proximity are confined to areas near or on the summits of the mountains and therefore do not overlap. These disjunct populations may be the result of competition from *P. cinereus* and *Desmognathus ochrophaeus* for certain limited resources (Pauley, unpublished data). *Plethodon*

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*This population was found by Brooks in 1938. Surveys in this area in 1978 and 1979 failed to produce *P. nettingi*. Since many *P. nettingi* sites are small in size, the exact location of this site may not have been found. Additional work is recommended here to determine the status of this population.

SCALE
1 centimeter = 7.6 kilometers

| 10 | 0 | 10 | 20 | 30 |

(After 1978 Official West
Virginia Highway Map)
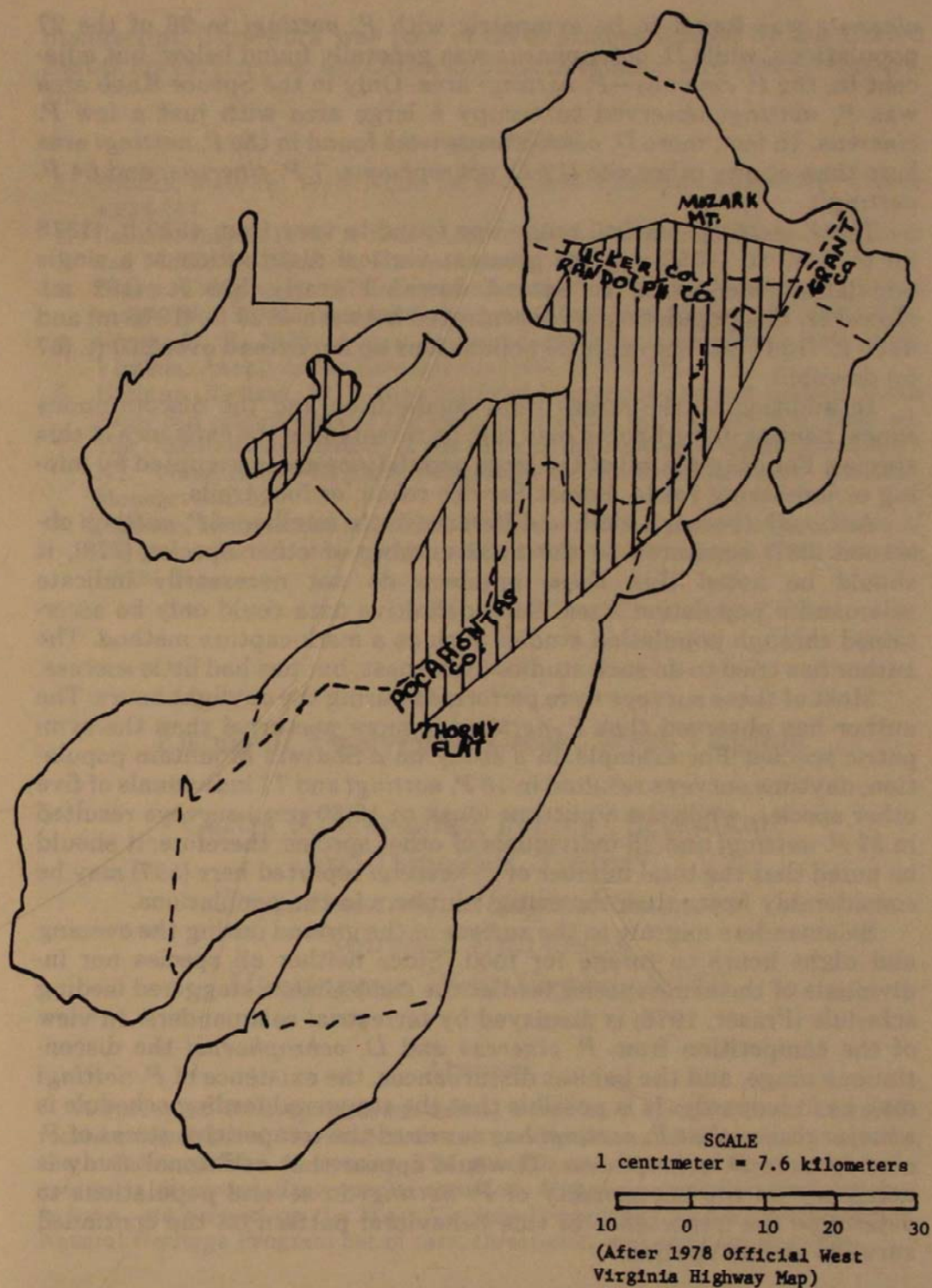
FIGURE 1. The total range of *P. nettingi*. The striped area in the West Virginia
map represents the Monongahela National Forest. The striped area in the
Monongahela National Forest represents the total range of *P. nettingi*.

cinereus was found to be sympatric with *P. nettingi* in 26 of the 27 populations, while *D. ochrophaeus* was generally found below, but adjacent to, the *P. cinereus—P. nettingi* area. Only in the Spruce Knob area was *P. nettingi* observed to occupy a large area with just a few *P. cinereus*. In fact, more *D. ochrophaeus* were found in the *P. nettingi* area here than at any other site (12 *D. ochrophaeus*, 7 *P. cinereus*, and 64 *P. nettingi*).

The *P. nettingi* vertical range was found to vary from 4520 ft. (1378 m) to 3450 ft. (1052 m). The greatest vertical distribution in a single population was found to extend downhill nearly 500 ft. (152 m). However, this population is concentrated between 4520 ft. (1378 m) and 4400 ft. (1341 m). The other 26 populations do not extend over 220 ft. (67 m) downhill.

In addition to the stress from competition and the discontinuous range, habitat disturbances may also be threatening the existence of this species. For example, all of the large populations are interrupted by mining or lumbering roads, Forest Service roads, or foot trails.

Although there is a marked difference in the number of *P. nettingi* observed (537) compared to the total number of other species (778), it should be noted that these numbers do not necessarily indicate salamander population sizes. Such definitive data could only be ascertained through population studies such as a mark-capture method. The author has tried to do such studies in the past, but has had little success.

Most of these surveys were performed during the daylight hours. The author has observed that *P. nettingi* is more nocturnal than the sympatric species. For example, in a study on a Shavers Mountain population, daytime surveys resulted in 16 *P. nettingi* and 77 individuals of five other species, while the nighttime (dusk to 10:30 p.m.) surveys resulted in 37 *P. nettingi* and 26 individuals of other species; therefore, it should be noted that the total number of *P. nettingi* reported here (537) may be considerably fewer than the actual numbers in the populations.

Salamanders migrate to the surface of the ground during the evening and night hours to forage for food. Since neither all species nor individuals of the same species feed at the same time, a staggered feeding schedule (Fraser, 1976) is displayed by terrestrial salamanders. In view of the competition from *P. cinereus* and *D. ochrophaeus*, the discontinuous range, and the habitat disturbances, the existence of *P. nettingi* may be in jeopardy. It is possible that the staggered feeding schedule is a major reason that *P. nettingi* has survived the competitive stress of *P. cinereus* and *D. ochrophaeus*. It would appear that additional study is necessary on the nocturnality of *P. nettingi* in several populations to determine the importance of this behavioral pattern on the continued survival of this species.

manuscript. This work was part of three studies funded by the United States Forest Service, the Office of Surface Mining, and Enviro Energy, Inc.

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Fishes of Twelvepole Creek, West Virginia

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Abstract

A survey of Twelvepole Creek fishes, based on a compilation of literature records, unpublished Marshall University collections, and recent collections by the authors, yielded 65 species. The possible occurrence of seven additional species is discussed. Two species recorded, *Hybopsis storeriana* and *Ictiobus bubalus*, are present on the West Virginia Department of Natural Resources, Natural Heritage Program list of rare, threatened, and endangered fishes.

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Introduction

Twelvepole Creek arises on Guyan Mountain in northern Mingo County, West Virginia, and flows in a northwest direction, discharging into the Ohio River near Ceredo, Wayne County, West Virginia. The main channel is formed from the junction of the East Fork and the West Fork approximately 2 km south of Wayne, Wayne County. From the point of confluence to the mouth, Twelvepole Creek is 49.9 km long with a mean gradient of 0.85 m/km (Krebs and Teets, 1913). The total drainage basin occupies an area of 753.7 km^2 (Erskine, 1942). A masonary dam located at Dickson was built in the 1930's at the site of the Falls of Twelvepole (Hardin, 1976). An oxbow lake is located off the main channel at Shoals, West Virginia. The East Fork is 80.4 km long, much of which was impounded by the U.S. Army Corps of Engineers in 1972, forming East Lynn Lake. The mean gradient before impoundment was 2.5 m/km (USACE, 1974). The West Fork has a length of 83.7 km and a mean gradient of 3.8 m/km. Beech Fork, a major tributary of the main stem of Twelvepole Creek, originates in eastern Wayne County and flows northwest 44.2 km to enter Twelvepole at Lavalette, West Virginia. The U.S. Army Corps of Engineers impoundment completed in 1977 inundated much of the stream channel, which had a mean gradient of 3.0 m/km (Krebs and Teets, 1913).

Previous published fish surveys on the Twelvepole Creek drainage include the following: (1) Tarter (1972) (38 species from the East Fork), (2) Olson and Tarter (1974) (35 species from Beech Fork), (3) Goodno (1974) (28 species from East Lynn Lake tailwaters), (4) Borda (1980) (31 species from Beech Fork), and (5) Hardman et al. (1980) (38 species from the West Fork). Goldsborough and Clark (1908) surveyed the fishes of West Virginia, but made no mention of the Twelvepole drainage. Jenkins et al. (1971) reviewed fishes of the central Appalachian drainages, but ignored Twelvepole Creek. Denoncourt et al. (1975) recently provided a checklist of West Virginia fishes. No comprehensive survey of Twelvepole Creek exists in the literature.

The ichthyofauna of the Twelvepole Creek drainage is complicated by the following: (1) influx of Ohio River species, (2) impoundment of two major tributaries, (3) subsequent stocking by the West Virginia Department of Natural Resources, and (4) the ever present fishermen's bait bucket.

Materials and Methods

This list of Twelvepole Creek fishes is based on a compilation of literature records, unpublished Marshall University collections, and recent collections by the authors. Twenty-seven (27) sampling stations were plotted during the investigation (Table 1). Previous collections made in currently impounded sections of Beech Fork and the East Fork were considered obsolete. No attempt was made to survey these impoundments.

Various sampling methods were utilized. Most recent collections by the authors and those on the West Fork (Hardman et al., 1980) were made with a 1.2 X 2.4 m nylon seine, with a 6.4 mm mesh. Rotenone was used at Stations 10 and 12 in the East Fork (Tarter, 1972) and in
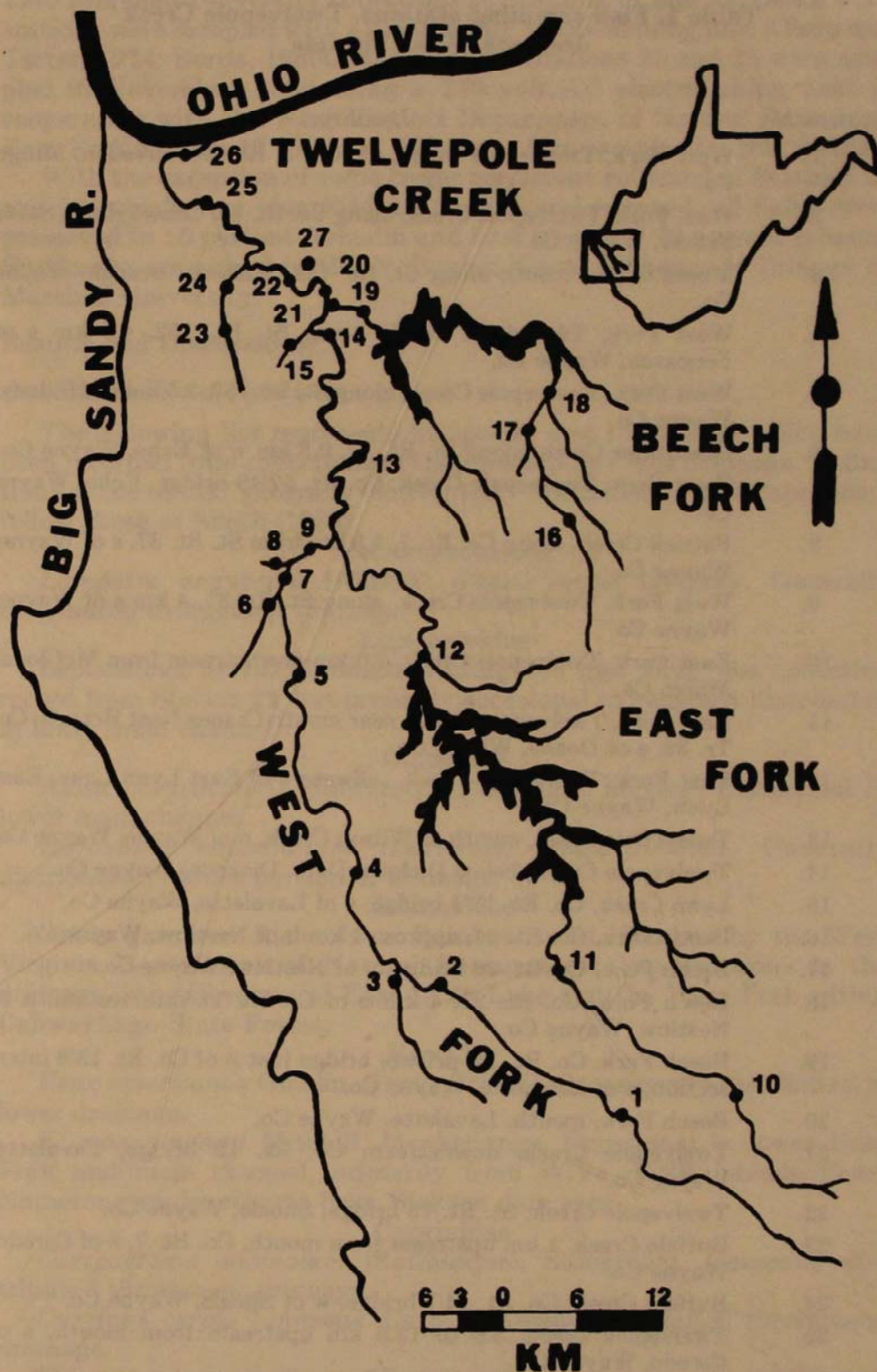
FIGURE 1. Map of Twelvepole Creek Drainage, West Virginia, showing collecting stations.

Table 1. Fish sampling stations, Twelvepole Creek drainage, West Virginia

Station No.	Locality
1.	West Fork, Twelvepole Creek, along Co. Rt. 3/5, Breeden, Mingo Co.
2.	West Fork, Twelvepole Creek, along Co. Rt. 35, Cabwaylingo State Forest, Wayne Co.
3.	Moses Creek, mouth along St. Rt. 152, Missouri Branch, Wayne Co.
4.	West Fork, Twelvepole Creek, along St. Rt. 152, 4.8 km s of Ferguson, Wayne Co.
5.	West Fork, Twelvepole Creek, along St. Rt. 152, 2.5 km s of Sidney, Wayne Co.
6.	Greenbrier Creek, along St. Rt. 37, 0.5 km w of Echo, Wayne Co.
7.	West Fork, Twelvepole Creek, Co. Rt. 52/49 bridge, Echo, Wayne Co.
8.	Patrick Creek, along Co. Rt. 7, 1.9 km from St. Rt. 37, s of Wayne, Wayne Co.
9.	West Fork, Twelvepole Creek, along St. Rt. 37, 4 km s of Wayne, Wayne Co.
10.	East Fork, Twelvepole Creek, 2.0 km downstream from McCloud, Mingo Co.
11.	East Fork, Twelvepole Creek, near mouth Cranes Nest Branch, Co. Tr. 39, e of Doane, Wayne Co.
12.	East Fork, Twelvepole Creek, tailwaters of East Lynn Lake, East Lynn, Wayne Co.
13.	Twelvepole Creek, mouth of Wilson Creek, n of Wayne, Wayne Co.
14.	Twelvepole Creek, below Dickson Dam, Dickson, Wayne Co.
15.	Lynn Creek, Co. Rt. 12/1 bridge, s of Lavalette, Wayne Co.
16.	Beech Fork, Co. Rt. 21, approx. 4 km n of Nestlow, Wayne Co.
17.	Beech Fork, Co. Rt. 26 bridge, n of Nestlow, Wayne Co.
18.	Beech Fork, Co. Rt. 21, 4 km n of Co. Rt. 26 intersection, n of Nestlow, Wayne Co.
19.	Beech Fork, Co. Rt. 13, private bridge just n of Co. Rt. 13/8 intersection, e of Lavalette, Wayne Co.
20.	Beech Fork, mouth, Lavalette, Wayne Co.
21.	Twelvepole Creek, downstream Co. Rt. 12 bridge, Lavalette, Wayne Co.
22.	Twelvepole Creek, St. Rt. 75 bridge, Shoals, Wayne Co.
23.	Buffalo Creek, 1 km upstream from mouth, Co. Rt. 7, s of Ceredo, Wayne Co.
24.	Buffalo Creek, Co. Rt. 14/1 bridge, w of Shoals, Wayne Co.
25.	Twelvepole Creek, 5.6 to 13.8 km upstream from mouth, s of Ceredo, Wayne Co.
26.	Twelvepole Creek, 3.4 to 5.6 km upstream from mouth, Ceredo, Wayne Co.
27.	Oxbow Lake, Co. Rt. 75/1, Shoals, Wayne Co.

1970 Marshall University collections at Stations 21 and 22. Beech Fork stations were sampled with a pulsated DC electrofishing unit (Olson and Tarter, 1974; Borda, 1980). Main channel Stations 25 and 26 were sampled in November, 1980 using a 240 volt AC electrofishing boat in cooperation with the West Virginia Department of Natural Resources. East Fork Station 12 (Goodno, 1974) was also sampled by this method.

With the exception of some larger specimens collected at Stations 25 and 26, which were identified in the field and released, all fishes were preserved in 10 percent formalin and later stored in 70 percent ethanol. Specimens are stored in the N. Bayard Green Museum of Zoology at Marshall University.

Results and Discussions

Annotated List of Species

The following list represents 65 species and 13 families which have been recorded from collections in the Twelvepole Creek drainage. Definitions of the terms "generally distributed," "occasional," and "sporadic" follow those of Smith (1965).

Petromyzontidae

Lampetra aepyptera (Abbott). Least brook lamprey. Generally distributed throughout drainage.

Lepisosteidae

Lepisosteus osseus (Linnaeus). Longnose gar. Only one collection record from Station 22, but probably occasional to generally distributed in lower main channel.

Clupeidae

Alosa chrysochloris (Rafinesque). Skipjack herring. Occasional in lower main channel.

Dorosoma cepedianum (Lesueur). Gizzard shad. Generally distributed in lower portion of drainage.

Salmonidae

Salmo gairdneri Richardson. Rainbow trout. Stocked by the West Virginia Department of Natural Resources at two locations in the drainage, the tailwaters of East Lynn Lake and the West Fork within Cabwaylingo State Forest.

Esocidae

Esox americanus Gmelin. Grass pickerel. Occasionally distributed in lower drainage.

E. masquinongy Mitchill. Muskellunge. Occasional in lower East Fork and main channel, primarily from W.Va. DNR introductions. Numerous angler reports from Dickson dam area.

Cyprinidae

Campostoma anomalum (Rafinesque). Stoneroller. Generally distributed throughout drainage.

Cyprinus carpio Linnaeus. Carp. Generally distributed throughout drainage.

Ericymba buccata Cope. Silverjaw minnow. Generally distributed throughout drainage.

Hybopsis amblops (Rafinesque). Bigeye chub. Occasional in East and West Forks.

Table 2. Occurrence of fish species at sampling stations, Twelvepole Creek, West Virginia

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Lampetra aepyptera	X		X				X				X					X	X	X	X	X	X	X	X	X			X
Lipisosteus osseus																						X					
Alosa chrysochloris																					X	X			X	X	
Dorosoma cepedianum														X					X	X				X			
Salmo gairdneri												X				X											
Esox americanus							X	X								X	X				X	X	X	X			X
E. masquinongy	X	X										X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Campostoma anomalum	X	X	X			X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyprinus carpio	X	X	X		X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ericymba buccata						X																					
Hybopsis amblops		X		X		X																					
H. storeriana																											
Nocomis micropogon		X		X			X		X					X			X	X	X	X	X	X	X	X	X	X	X
Notemigonus crysoleucas											X	X	X				X	X	X		X	X	X		X		
Notropis atherinoides											X	X	X				X	X	X		X	X	X				
N. chrysocephalus		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N. photogenis		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X			
N. rubellus			X		X				X																		
N. stramineus		X						X																			
N. umbratilus								X							X					X		X					
N. volucellus									X									X									
Phenacobius mirabilis						X	X								X	X	X						X				
Phoxinus erythrogaster	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X			
Pimephales notatus	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rhinichthys atratulus	X	X	X		X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Semotilus atromaculatus	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Carpiodes carpio																											
C. cyprinus	X	X				X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Catostomus commersoni	X	X	X			X	X		X	X		X	X			X	X	X		X	X	X	X	X	X	X	
Hypentelium nigricans	X	X	X			X	X		X	X		X	X			X	X	X	X	X	X	X				X	

Ictiobus bubalus
Minytrema melanops
Moxostoma anisurum
M. carinatum
M. erythrurum
M. macrolepidotum
Ictalurus melas
I. natalis
I. punctatus
Noturus miurus
Pylodictis olivaris
Percopsis omiscomaycus
Labidesthes sicculus
Ambloplites rupestris
Lepomis cyanellus
L. macrochirus
L. megalotis
Micropterus dolomieui
M. punctulatus
M. salmoides
Pomoxis annularis
P. nigromaculatus
Ammocrypta pellucida
Etheostoma blennoides
E. caeruleum
E. flabellare
E. nigrum
E. variatum
E. zonale
Percina caprodes
P. maculata
P. sciera
Stizostedium canadense
S. vitreum
Aplodinotus grunniens

H. storeriana (Kirtland). Silver chub. One specimen from Station 25, probably occasional in lower main channel. On Natural Heritage Program, W.Va. DNR, list of rare, threatened, and endangered fishes.

Nocomis micropogon (Cope). River chub. Generally distributed throughout drainage.

Notemigonus crysoleucas (Mitchill). Golden shiner. One specimen taken at Station 21, possibly sporadic or introduced.

Notropis atherinoides Rafinesque. Emerald shiner. Very common in lower main channel, absent from upper drainage.

N. chrysocephalus (Rafinesque). Striped shiner. Generally distributed throughout drainage.

N. photogenis (Cope). Silver shiner. Occasional, primarily in upper drainage.

N. rubellus (Agassiz). Rosyface shiner. Generally distributed throughout drainage.

N. stramineus (Cope). Sand shiner. Generally distributed throughout drainage.

N. umbratilus (Girard). Redfin shiner. Occasional, records from upper Beech Fork, Station 14 on the main channel, and from a now impounded section of the East Fork.

N. volucellus (Cope). Mimic shiner. Collected at Station 9 of the West Fork and 22 on main channel. Sporadic throughout drainage.

Phenacobius mirabilis (Girard). Suckermouth minnow. One specimen each from Station 19 and 22. Apparently sporadic to occasional in occurrence.

Phoxinus erythrogaster (Rafinesque). Redbelly dace. Generally distributed in small tributaries.

Pimephales notatus (Rafinesque). Bluntnose minnow. Generally distributed throughout drainage.

Rhinichthys atratulus (Hermann). Blacknose dace. Generally distributed in small tributaries.

Semotilus atromaculatus (Mitchill). Creek chub. Generally distributed throughout drainage.

Catostomidae

Carpiodes carpio (Rafinesque). River carpsucker. Occasional in lower main channel.

C. cyprinus (Lesueur). Quillback carpsucker. Occasional to generally distributed in lower main channel. One record from the lower East Fork.

Catostomus commersoni (Lacepede). White sucker. Generally distributed throughout drainage.

Hypentelium nigricans (Lesueur). Hog sucker. Generally distributed throughout drainage.

Minytrema melanops (Rafinesque). Spotted sucker. Generally distributed, less common in upper drainage.

Moxostoma anisurum (Rafinesque). Silver redhorse. Occasional, primarily in lower drainage.

M. carinatum (Cope). River redhorse. Collected only at Station 25, probably occasional in lower main channel.

M. erythrurum (Rafinesque). Golden redhorse. Generally distributed throughout drainage.

M. macrolepidotum (Lesueur). Shorthead redhorse. Occasional in lower drainage.

Ictiobus bubalus (Rafinesque). Smallmouth buffalo. One specimen taken at Station 26, probably occasional to sporadic in lower main channel. On Natural Heritage Program, W.Va. DNR, list of rare, threatened, and endangered fishes.

Ictaluridae

Ictalurus melas (Rafinesque). Black bullhead. Generally distributed in lower drainage. Uncommon to absent in upper East and West Forks, except East Lynn Lake, where it is common.

I. natalis (Lesueur). Yellow bullhead. Occasional, most records coming from upper drainage.

I. punctatus (Rafinesque). Channel catfish. Generally distributed in lower main channel. Absent in upper drainage, except lower East Fork and East Lynn Lake from introductions.

Noturus miurus Jordan. Brindled madtom. Generally distributed throughout drainage.

Pylodictis olivaris (Rafinesque). Flathead catfish. Immature individuals collected at Stations 14 and 22. Occasional in lower main channel.

Percopsidae

Percopsis omiscomaycus (Walbaum). Troutperch. Occasional throughout drainage, appear to be declining in numbers. Recent collecting in lower Beech Fork failed to produce specimens in an area of former abundance.

Atherinidae

Labidesthes sicculus (Cope). Brook silverside. Occasional in East Fork and lower drainage. Stocked in East Lynn Lake.

Centrarchidae

Ambloplites rupestris (Rafinesque). Rock bass. Generally distributed throughout drainage.

Lepomis cyanellus Rafinesque. Green sunfish. Occasional throughout drainage.

L. macrochirus Rafinesque. Bluegill. Occasional in upper drainage to generally distributed in lower drainage.

L. megalotis (Rafinesque). Longear sunfish. Generally distributed throughout drainage.

Micropterus dolomieui Lacepede. Smallmouth bass. Occasional to uncommon in upper drainage, declining in numbers.

M. punctulatus (Rafinesque). Spotted bass. Generally distributed throughout drainage.

M. salmoides (Lacepede). Largemouth bass. Occasional, primarily in lower drainage.

Pomoxis annularis Rafinesque. White crappie. Occasional in lower drainage.

P. nigromaculatus (Lesueur). Black crappie. Introduced in East Lynn and Beech Fork lakes. Recorded from East Fork at Station 12. Probably occasional in lower drainage.

Percidae

Ammocrypta pellucida (Putnam). Eastern sand darter. Single

specimens taken at Stations 14 and 22. Occasional to sporadic in lower drainage, probably declining in numbers.

Etheostoma blennoides Rafinesque. Greenside darter. Generally distributed throughout drainage.

E. caeruleum Storer. Rainbow darter. Occasional in upper drainage.

E. flabellare Rafinesque. Fantail darter. Generally distributed throughout drainage.

E. nigrum Rafinesque. Johnny darter. Generally distributed throughout drainage.

E. variatum Kirtland. Variegate darter. Occasional throughout drainage.

E. zonale (Cope). Banded darter. Generally distributed throughout drainage.

Percina caprodes (Rafinesque). Logperch. Generally distributed throughout drainage.

P. maculata (Girard). Blackside darter. Generally distributed throughout drainage.

P. sciera (Swain). Dusky darter. Occasional throughout drainage.

Stizostedium canadense (Smith). Sauger. Occasional to generally distributed in lower main channel.

S. vitreum (Mitchill). Walleye. Occasional in lower main channel, probably due to W.Va. DNR stocking in East Lynn and Beech Fork lakes. However, one specimen taken at Station 21 occurred before introductions, indicating at least a sporadic natural occurrence.

Sciaenidae

Aplodinotus grunniens Rafinesque. Freshwater drum. Occasional to generally distributed in lower main channel.

Additional Fishes

The following list of seven species represents fishes appearing in past collections that are of uncertain status. Other fishes known from the main channel of the Ohio River may occasionally enter the lower Twelvepole drainage.

Amia calva Linnaeus. Bowfin. A single specimen was reported collected by the U.S. Army Corps of Engineers personnel (pers. comm.) in the Beech Fork Lake tailwaters. This either represents an introduction or a possible sporadic occurrence.

Dorosoma petenense (Gunther). Threadfin shad. Stocked in East Lynn Lake by W.Va. DNR and reported from tailwaters by Goodno (1974). Winterkill presumably extirpated the species.

Notropis blennius (Girard). River shiner. Recorded in one Marshall University collection from a now impounded site on Beech Fork. Expected in lower drainage.

Notropis spilopterus (Cope). Spotfin shiner. Reported by Tarter (1972) at one station in a now impounded section of the East Fork. Not reported in surveys since, but may occur sporadically.

Morone chrysops (Rafinesque). White bass. One angler report (pers. comm.) from the lower main channel. May occur occasionally in lower drainage.

Lepomis auritus (Linnaeus). Redbreast sunfish. Stocked at East Lynn Lake by W.Va. DNR, but has not been collected at any downstream locations.

L. humilis (Girard). Orangespotted sunfish. Reported by W.Va. DNR sampling at East Lynn Lake. Presumably introduced.

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A Method for Determining the Level of Aerobic Shutdown in Small Aquatic Organisms

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Abstract

A method is presented for a precise determination of the level of dissolved oxygen at which aerobic shutdown occurs in small aquatic organisms. The method involves the use of a modified Warburg respirometer flask and an electronic blood-gas analyzer. Data are presented on the level of aerobic shutdown in the larva of the phantom midge, *Chaoborus punctipennis* Say.

Introduction

Aerobic shutdown, the shift from aerobic to anaerobic metabolic pathways, as a response to declining environmental oxygen tensions has been extensively reported among the marine invertebrate phyla (Bayne, 1967; Teal and Carey, 1967; Theede et al., 1973). Mangum and Van Winkle (1973) published a list of 16 species (Table 1) from seven of the marine invertebrate phyla in which aerobic shutdown was demonstrated. Reconsideration of the older literature indicates that, although the term aerobic shutdown was not used and anaerobic respiration was not discussed, references to cessation of oxygen consumption and subsequent survival were indeed describing the same mechanism (May, 1972). In fact, Berg et al. (1962), studying oxygen consumption rate ($\dot{V}O_2$) in relation to environmental oxygen partial pressure (PO_2) for the benthic community of a freshwater lake with an extensive hypoxic hypolimnion, described a response similar to aerobic shutdown for *Chironomus anthracinus, Tubifex tubifex, Corethra (= Chaoborus) flavicans, Lumbricillus rivalis*, and *Pisidium casertanum*. Since the mechanism of aerobic shutdown has been widely described in marine invertebrates, and further since many freshwater invertebrates demonstrate the same respiratory responses as their marine counterparts, one reason that the mechanism has not been studied in freshwater invertebrates is the lack of an appropriate methodology. Respiratory measurements on freshwater organisms are frequently made with manometric devices (Wells and Warinner, 1968) or *in situ* with an oxygen probe (Arnold and Keith, 1976; Swain et al., 1976) neither of which afford an acceptable degree of sensitivity. In addition to the considerations of temperature and barometric pressure changes which are en-

Table 1. Aerobic Shutdown Levels for 22 Marine Invertebrate Species (from Mangum and van Winkle, 1973)

Phylum	Species	Shutdown PO_2 (mm Hg)
Cnidaria	*Diadumene leucolena*	15 - 55
Nemertina	*Cerebratulus lactens*	11 - 16
Annelida	*Capitella capitata*	0 - 34
	Polydora ligni	6 - 18
	Diopatra cuprea	0 - 25
Mollusca	*Lunatia heros*	5 - 7
	Modiolus demissus	5 - 8
	Rangia cuneata	4 - 13
	Urosalpinx cinerea	4 - 8
Arthropoda	*Palaemonetes pugio*	0 - 8
	Rhithropanopeus harrisi	0 - 4
	Squilla empusa	5 - 7
Echinodermata	*Echinarachnius parma*	21 - 31
	Leptosynapta inherens	0 - 22
	Thyone briareus	0 - 6
Urochordata	*Ciona testudinalis*	14 - 17

countered in simple oxygen consumption determinations, in aerobic shutdown determinations there is the need to maintain an anoxic atmosphere above the water in the system, to prevent the dissolution of atmospheric oxygen into the water, after aerobic shutdown has occurred. The methodology presented herein accommodates all of these considerations.

Materials and Methods

Fourth instar *Chaoborus* larvae were collected from anoxic bottom sediments of local lakes with an Ekman grab (15 x 15 cm). The larvae were screened from the sediments immediately, placed in containers of lake water, packed on ice, and transported to the laboratory. They were maintained in five aquaria in environmental chambers at 10 C. Since larvae were collected regularly and maintained at 10 C, they did not require any feeding during the maintenance period (usually less than three weeks).

The apparatus (Figure 1) used to determine the aerobic shutdown level for *Chaoborus* was a modified Warburg respirometer flask. The organism (A) was placed in 10 ml of water in the flask (B). After a period of acclimation, the stopcock (C) was closed, sealing the system. Since a piece of filter paper saturated with an aqueous sodium hydroxide solution was placed in one of the sidearms (D) to absorb any carbon dioxide produced in respiration, the only volume change in the flask was the decrease due to oxygen consumption by the organism. The rate of

A = organism
B = flask
C = stopcock
D = NaOH-saturated filter paper in sidearm
E = Brodie's fluid level
F^1, F^{11} = valves (F^{11} is identical to F^1, and is located on an identical sidearm not shown)
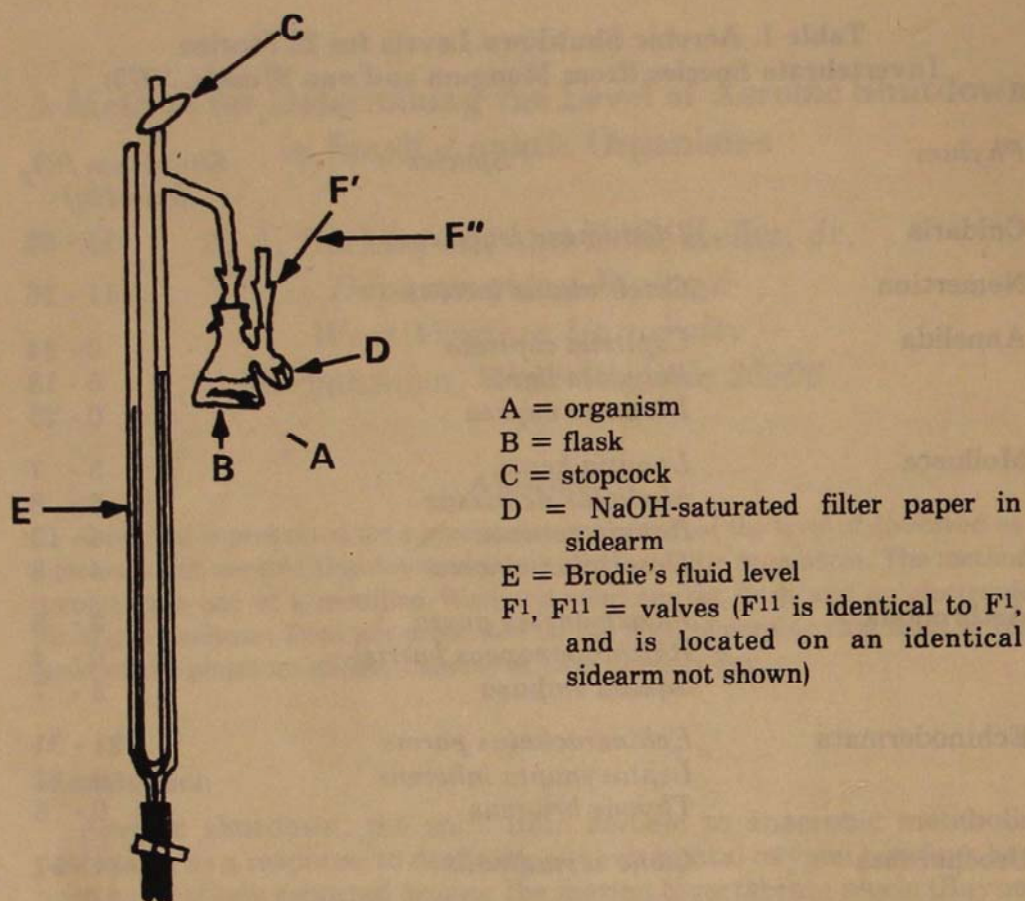
FIGURE 1. Warburg respirometer apparatus, as modified for aerobic shutdown level determination for *Chaoborus* (after Umbreit et al., 1964).

oxygen consumption was calculated from the change in manometer fluid (Brodie's fluid) level (E) (Figure 1). When there was no further change in the manometer fluid level, oxygen consumption had ceased, and aerobic shutdown was considered to have occurred. At this point, the valves (F^1 and F^{11}) were opened and nitrogen was introduced to displace any oxygen in the atmosphere within the flask. While a flow of nitrogen was maintained through the flask, valve F^{11} was removed and a 100 ml sample of the water was withdrawn by syringe. The PO_2 of the water at shutdown level, in the flask was measured, using a Radiometer type E-5046 oxygen electrode with a PHM 71 acid base analyzer.

Results and Discussion

Measurements of 24 larvae indicated that aerobic shutdown occurred at a PO_2 level 52.2 ± 5.4 mm Hg. Comparison of these data with those of Mangum and Van Winkle (1973) (Table 1), places *Chaoborus* at the upper end of the range of shutdown PO_2's for the species studied.

The fourth instar larvae of *Chaoborus punctipennis* Say are benthic diurnally, but emerge from the bottom mud, migrate through the water

column and enter the top few meters nocturnally (Berg, 1937; Main, 1953; Saether, 1972). McLaren (1963) proposed an explanation for diurnal vertical migration based on the energetic advantage derived from more efficient partitioning of energy into growth and maintenance metabolism, permitted by migration between areas of high and low temperatures. However, Swift (1974), based on observations of the *Chaoborus trivittatus* population of Eunice Lake, British Columbia, and extensive computer simulation, concluded that the energetics theory of McLaren alone was insufficient to explain the vertical migration in all *Chaoborus* populations. He proposed that the adaptive significance varies from group to group depending on such factors as food availability and predation pressure. Regardless of the evolutionary significance of the migration, in many lakes, it exposes the larvae to hypoxic or even anoxic conditions during the period in which they are benthic and it is not surprising that they developed the mechanism of aerobic shutdown to deal with such conditions.

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A Method for Behavior Modification in Aquatic Crustaceans

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Abstract

A method is presented for negatively reinforcing emersion behavior in the green crab, *Carcinus maenas* (L.), in response to environmental hypoxia. The method involves the use of a rotating striker assembly, in a standard respirometer chamber, arranged so as to strike the carapace of an animal, attempting to emerse from the water. The significance of the reinforcement experiments is discussed in relation to the role of the emersion behavior as one component of a mixed-strategy of respiratory responses to hypoxia.

Introduction

The usual response of the green crab, *Carcinus maenas* (L.) to hypoxic conditions in its environment is emersion. This involves raising the anterior carapace above the surface of the water, reversing the direction of scaphognathite beat, and thus filling the branchial chambers with air. As long as the gills remain moist, the crab can obtain sufficient oxygen from aerial respiration to maintain normal aerobic metabolism. Becker and Bayne (1976) and Becker (1979) showed that *Carcinus* also responds to environmental hypoxia by the mechanism of aerobic shutdown. This involves complete cessation of ventilatory activity, accompanied by a shift from aerobic to anaerobic metabolic pathways (Mangum and Van Winkle, 1973). In our experiments, aerobic shutdown had definitely occurred, as measured by a complete cessation of oxygen consumption in the respirometer chamber and the appearance of anaerobic metabolic end-products in the hemolymph (Burke, 1979).

Is anaerobic metabolism actually used by the animal in its natural environment, or is it an artifact of experimental methodologies? This question arose because in the laboratory experiments, the animals had been functionally prevented from emersing. (They were placed in respirometer chambers which were either completely filled with water [Becker and Bayne, 1976] or partially filled with water with the remaining air space flushed with nitrogen [Becker, 1979]). We therefore decided to determine if aerobic shutdown would occur in animals which had a choice between emersion, allowing for aerobic respiration, and continued immersion with its requisite aerobic shutdown, which would necessitate anaerobic respiration. This was done by retaining the normoxic atmosphere in the respirometer chamber above the water, but by negatively reinforcing emersion.
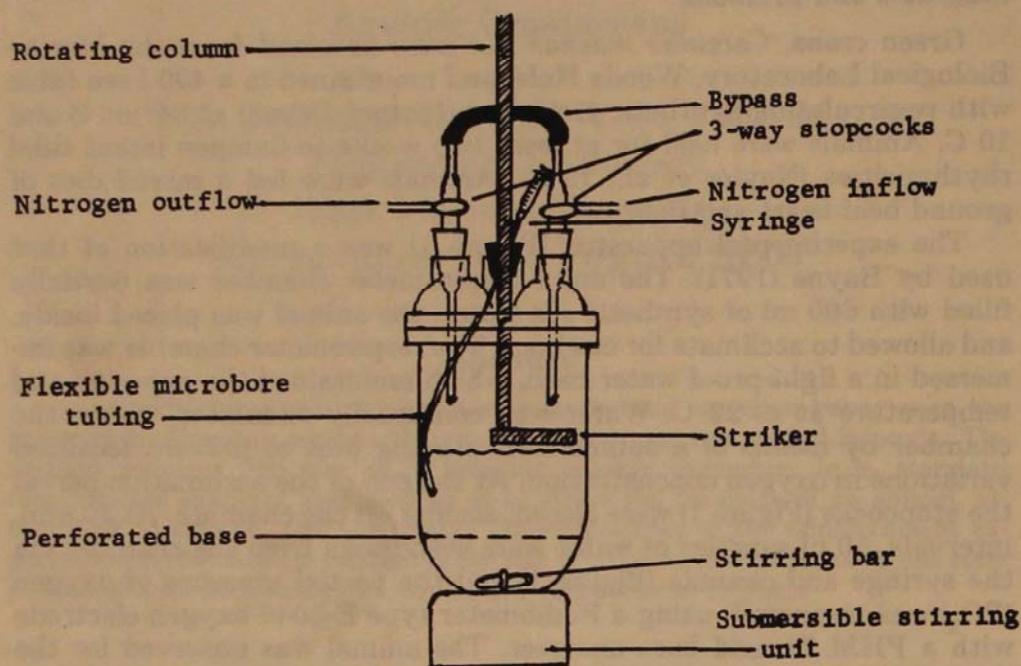
Materials and Methods

Green crabs, *Carcinus maenas* (L.) were obtained from the Marine Biological Laboratory, Woods Hole, and maintained in a 400 l sea table with re-circulating synthetic sea water (Instant Ocean) at 34°/oo S and 10 C. Animals were held for at least two weeks to dampen latent tidal rhythmicities (Naylor et al., 1973). Animals were fed a mixed diet of ground beef heart and fish.

The experimental apparatus (Figure 1) was a modification of that used by Bayne (1971). The one l respirometer chamber was partially filled with 600 ml of synthetic sea water, the animal was placed inside, and allowed to acclimate for one hour. The respirometer chamber was immersed in a light-proof water bath, which maintained the experimental temperature at c. 22 C. Water was continually circulated within the chamber by means of a submersible stirring unit to prevent localized variations in oxygen concentration. At the end of the acclimation period the stopcocks (Figure 1) were closed, sealing off the chamber. At 30 min. intervals, 50 ul samples of water were withdrawn from the chamber via the syringe and cannula (Figure 1) and the partial pressure of oxygen (PO_2) was measured, using a Radiometer type E-5046 oxygen electrode with a PHM 71 acid base analyzer. The animal was observed for the emersion response and the PO_2, at which emersion occurred, was recorded. When subsequent PO_2 determinations indicated that there had been no decrease in PO_2, within the chamber, for the period of one hour, aerobic shutdown was considered to have occurred and the experiment was terminated.

Animals were studied under three conditions, normoxic atmosphere, nitrogen atmosphere and negative reinforcement. In the nitrogen experiments, following acclimation, the air was displaced from the chamber with nitrogen and a nitrogen atmosphere was maintained above the water. In the negative reinforcement experiments, a metal rod with a piece of soft tubing attached perpendicularly at its lower end (Figure 1) was placed in the center of the chamber. The rod was rotated (c. 50 rpm) in such a way that the tubing swept the area of the chamber, a few millimeters above the water surface. If a crab were emersing from the water, it would be tapped by the rotating tubing. The tubing was sufficiently pliable that it would brush the carapace without dislodging the crab and physically re-immersing it. In all cases the PO_2 of the water, at the points where the animal initially emersed and where it subsequently ceased emersion behavior and re-immersed, were determined.

Results

Emersion occurred at approximately the same PO_2 in all cases: 68.6 ± 11.3 mmHg in a normoxic atmosphere, 64.9 ± 16.1 mmHg in a nitrogen atmosphere, and 69.1 ± 13.4 mmHg in the case of negative reinforcement (Figure 2). In a normoxic atmosphere, the animals remained emersed and continued aerial respiration until the experiment was terminated. Emersion behavior continued to a slightly lower PO_2 in the case of the negative reinforcement experiments, but in both cases the

Rotating column

Bypass
3-way stopcocks

Nitrogen outflow

Nitrogen inflow
Syringe

Flexible microbore
tubing

Striker

Perforated base

Stirring bar

Submersible stirring
unit

RESPIROMETER CHAMBER

FIGURE 1. A diagram of the respirometer chamber used in the negative reinforcement experiments, showing the striker mechanism rotated by a variable speed motor (not shown).

animals eventually returned to the water and resumed aerobic aquatic respiration.

The point, at which emersion occurred, corresponded with a transition from oxyregulation to oxyconformation. That is to say, at PO_2's above this point, oxygen consumption ($\dot{V}O_2$) remained essentially constant, despite changes in environmental PO_2. Below this point $\dot{V}O_2$ decreased with decreasing PO_2 (Mangum, et al., 1970).

The $\dot{V}O_2$ continued to decrease with decreasing PO_2 until aerobic shutdown occurred. This was at 23.1 ± 4.7 mmHg in the nitrogen atmosphere experiments and at 23.8 ± 3.0 mmHg in the negative reinforcement experiments. Of course, aerobic shutdown never occurred in the normoxic atmosphere experiments.

Discussion

The data would indicate that *Carcinus* demonstrates a "mixed-strategy" (Maynard Smith, 1976) for dealing with environmental hypoxia. That is to say that, when exposed to declining environmental oxygen tensions, *Carcinus* emerses and carries out aerobic aerial respiration. However, *Carcinus* is also, under certain circumstances, capable of responding to hypoxia by initiating aerobic shutdown.

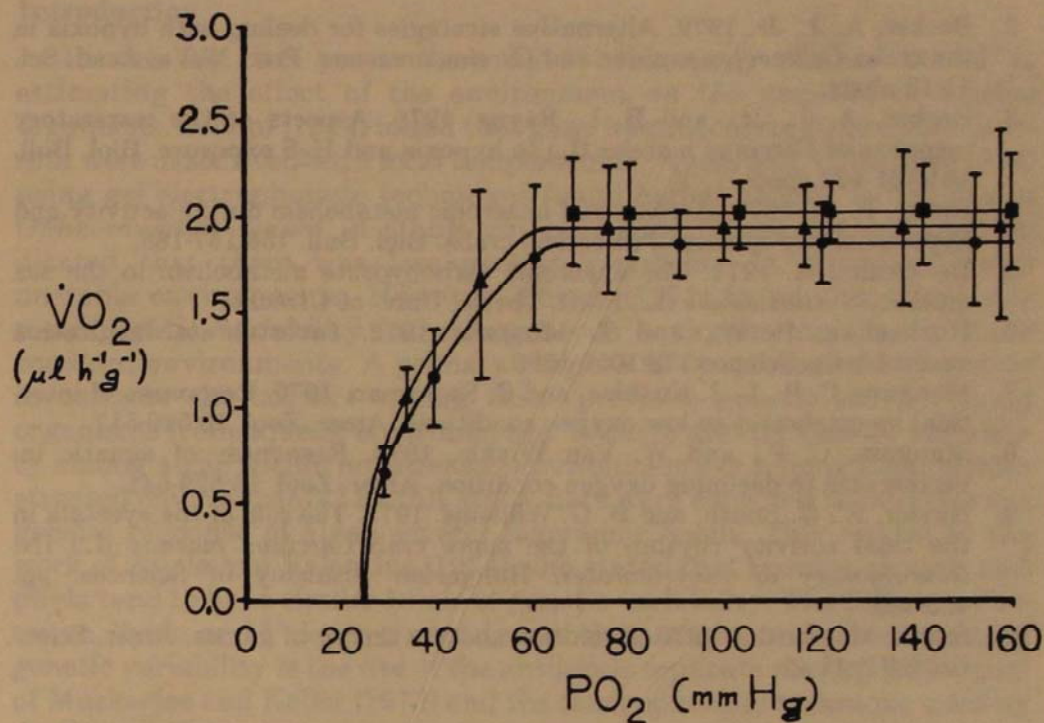The point at which emersion occurred is intuitively satisfying, since a

FIGURE 2. The oxygen consumption rates (VO₂) and shutdown levels (PO₂) for the three experimental conditions (circles = negative reinforcement, triangles = nitrogen atmosphere, squares = normoxic atmosphere).

shift from oxyregulation to oxyconformation, that is a shift from oxygen independence to dependence, indicates that continued aquatic respiration is more metabolically expensive. Thus it may be more efficient metabolically to make the transition from aquatic to aerial respiration. However, if aerobic aerial respiration is prevented as in the case of a nitrogen atmosphere, or if it is negatively reinforced, the animal will adopt the less efficient aquatic form of respiration.

It is significant that the anaerobic pathways which *Carcinus* utilizes during aerobic shutdown are considerably less metabolically efficient than the aerobic pathways used in either aquatic or aerial aerobic respiration (DeZwaan, 1971; Hochachka and Mustafa, 1972). We would propose that routinely, when confronted with hypoxic conditions, *Carcinus* emerses; however, if the air itself is hypoxic or anoxic, as may sometimes be the case when significant quantities of ammonia, methane or hydrogen sulfide develop in salt marshes, it may be adaptive for the animal to use the alternative mechanism of aerobic shutdown. The same is true in the case of a normoxic atmosphere if the emersion response is negatively reinforced as might be the case in areas where avian predation pressure is particularly intense.

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Antibiotic Resistance of Periphyton Isolated from Three Aquatic Environments

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Abstract

Periphyton from several different aquatic environments were examined for their degree of antibiotic resistance. The periphyton were isolated from 1" x 3" glass microscope slides that were suspended in a water column for a period of 14 days. Biweekly samples were obtained from streams that were characterized as 1) the Ohio River, 2) nonstressed, and 3) stressed environment. The growth of the periphyton on 32 gene (antibiotic) markers was accomplished by use of a replicate plating technique.

Tukey's (1977) smoothing technique was applied to the resultant data from the biweekly samples to determine those changes that occurred in the levels of antibiotic resistance throughout the study. The results indicate that changes in the frequency of antibiotic resistance of the periphyton isolates occurred during the study. Among the algae isolated from the various environments and among the various taxonomic levels.

Introduction

In the last ten years there have been many studies aimed at estimating the effect of the environment on the genetics of marine organisms. Schopf (1974) found that gene frequencies in *Schizoporella errata* were associated with local temperatures. Ayala and Valentine (1974) using gel electrophoretic techniques found higher genetic variability in *Opheomusium lynani* in stable environments. These authors also indicated that there was less genetic variability in organisms from unstable environments. However, Powell (1971) found that there was more genetic variability in heterogeneous environments than in more constant environments. A primary purpose of the present study was to investigate the conflict among these previous genetic studies using organisms from aquatic environments. Is there greater genetic variability among algae within nonstressed environments or among algae within stressed environments? In this study data were collected to evaluate the genetic response of algae several taxonomic levels. This relates to the work of Ayala and Valentine (1974) who stated that species, classes, and phyla tend to have similar levels of genetic variability. The difference between Ayala and Valentine's study and the present study in estimating genetic variability is the use of the antibiotic replicate plating technique[1] of Murkerjee and Keller (1973) and the electrophoretic technique used by Ayala and Valentine.

Materials and Methods

Ten sites in northern West Virginia and southwestern Pennsylvania were sampled biweekly from April 1977 through February 1978. These sites were chosen to represent three different aquatic environments viz.: 1) nonstressed environments, 2) the Ohio River, and 3) stressed environments. Three sites located in Hancock, Brooke, and Marion counties, West Virginia, were chosen to assess the nonstressed environment. These sites do not receive appreciable steel mill, mine drainage, or sewage effluents. The Ohio River samplings were done at two sites located near the cities of Wellsburg and Weirton, West Virginia. The third environment (stressed) assessed three types of individual environments. One stress was a steel mill effluent at one site in Harmon Creek in Weirton, West Virginia. The second stress (sewage effluents) involved samples from two sites, Falling Run and Pompano Run, near the cities of Morgantown and Star City, West Virginia. The third stress (mine drainage effluents) involved sampling a site in Robinson Run, near Star City, West Virginia, and a site in Camp Run, near Point Marion, Pennsylvania.

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[1]This technique involves the use of 115 capillary tubes held on a movable platform. The pattern area of the capillary tubes is just slightly smaller than a standard size petri dish. The tubes are filled with unialgal inocula from 115 test strains. These tubes are lowered onto sterile agar plates containing various test antibodies and the last petri dish contained only algal nutrient medium. The different antibiotic test plates thereby received identical inocula.

The algal species that were genetically assayed in the three environments were isolated from biweekly periphyton samples. The periphyton samples were obtained from 1" x 3" glass microscope slides that were placed in a periphyton sampler for a period of 14 days at which time the slides were removed and replacement slides were inserted into the sampler. The periphyton sampler was a modification of periphyton samplers used by Patrick, Hohn, and Wallace (1954); Mitchell (1974); and Patrick (1973).

The biweekly algal samples were removed from the miscroscope slides by scraping them into petri dishes. Water from the site was added to the petri dish until the final volume of algae and stream water totaled 20 mls; which was then poured into a previously coded seven dram vial. Upon arriving at the laboratory a 0.5 ml portion of the algae was plated on Chu or Beyerinck algal medium. The algal plates were then placed in a fluorescent lighted (c. 301 lux) constant temperature chamber at 18°C for a period of 21 days. After that time, unialgal liquid cultures of either Beyerinck or Chu medium were made of all species present on the algal plates by using a Baush and Lomb dissecting microscope at 30 x magnification. After a period of six months, which was sufficient time to allow the unialgal populations to increase in size, 115 unialgal cultures were inoculated on Beyerinck or Chu medium containing an LC-50 concentration of one of 32 antibiotics using the replicate plating technique of Murkerjee and Keller (1973). The innoculated Chu or Beyerinck plates were then placed in the constant temperature chamber for a period of 21 days. After which the frequencies for each taxonomic level was estimated on each antibiotic using the binomial scoring technique[2] described by Moll and Keller (1981).

Data produced in this manner were analyzed by using the Statistical Analysis System (Barr, et al., 1979) and an AMDAHL 470 computer. Then, the general trends in the genetic data were ascertained using the curve smoothing techniques of Anderson (1971) and Tukey (1977).

Results

Estimates of the biweekly gene frequencies for two genetic markers (antibiotics) estimated for species (triangles), genus (hexagon), phyla (circles) and "all" algal (squares) aspects are presented in Figure 1. Of the two antibiotics presented, one is an inhibitor of cell wall synthesis (ampicillin•$3H_2O$) and the other is an inhibitor of protein synthesis (tetracycline•HC1). Figure 1 shows that resistance to both antibiotics is high in spring (April-June) and in the late fall to early winter (November-December). Conversely, resistance to both antibiotics is lower during the summer (July-October) and late winter (January-February) periods. Also, this general trend exists at all taxonomic levels for both antibiotics. Further, note that level of genetic resistance to the cell wall in-

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[2]This technique involved a simple scoring of growth (1) or no growth (0) of the various algal strains on the different antibiotic media.
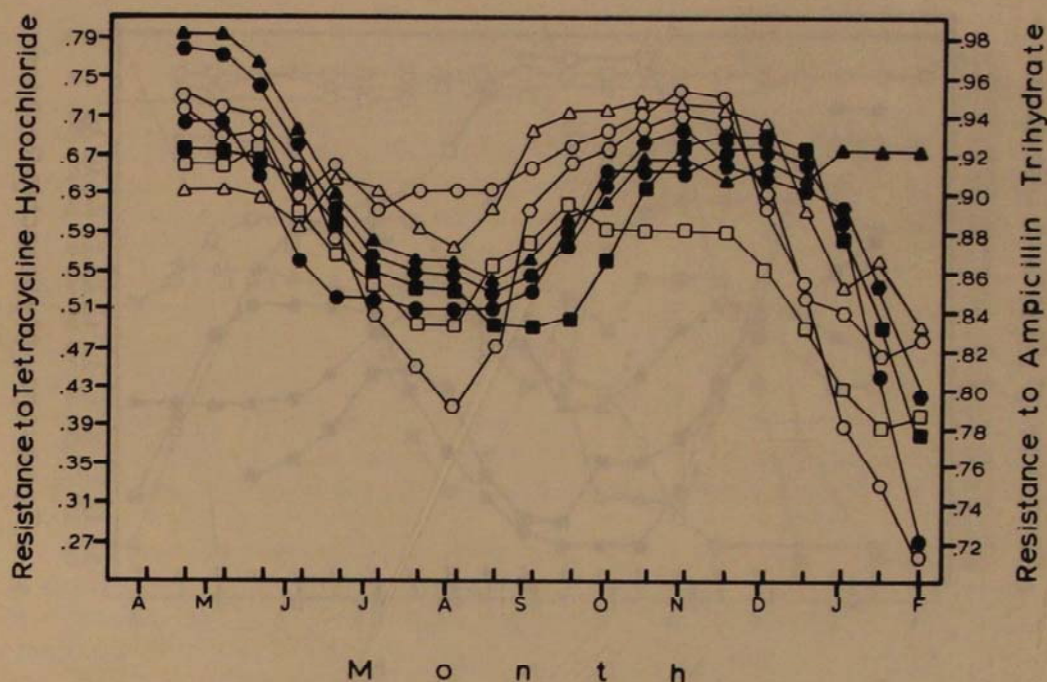
FIGURE 1. Biweekly frequencies of resistance to ampicillin•3H₂O (open symbols) and tetracycline HC1 (black symbols) estimated at four taxonomic levels (triangles = species, hexagons = genus, circles = phyla, and squares = all algae studied) isolated from algae grown on artificial substrates.

hibition antibiotic occurs at a higher level than the level of resistance to the protein synthesis inhibitor.

While Figure 1 illustrates the relationship of these two genetic markers across all taxonomic levels it does not illustrate the effect that the various environments have on any one particular taxonomic level. Figure 2 shows the individual genus level effect in three environments in response to antibiotic resistance of the protein synthesis inhibitor, tetracycline. The two genera illustrated in Figure 2 are *Chlorella* (closed symbols) and *Nitzschia* (open symbols) which represent two of the dominant organisms within all three environments.

Chlorella and *Nitzschia* from the Ohio River (squares on Figure 2) show almost opposite patterns of antibiotic resistance until November when resistance to tetracycline declines in both genera. *Chlorella* from the Ohio River were found to show moderately high resistance in April and May and showed a decrease from these levels during the summer months; while tetracycline resistance in *Nitzschia* increased during the summer months in the Ohio River environment.

The frequency of tetracycline resistance of *Chlorella* isolates in the stressed environment (triangles in Figure 2) changed very little (from 0.60 to 0.75) during the study period, even though the two peak antibiotic resistance periods occurred in late-spring/early-summer and in the fall. The frequency of resistance to tetracycline in *Nitzschia* from the stressed environment showed a highly variable response (ranging from
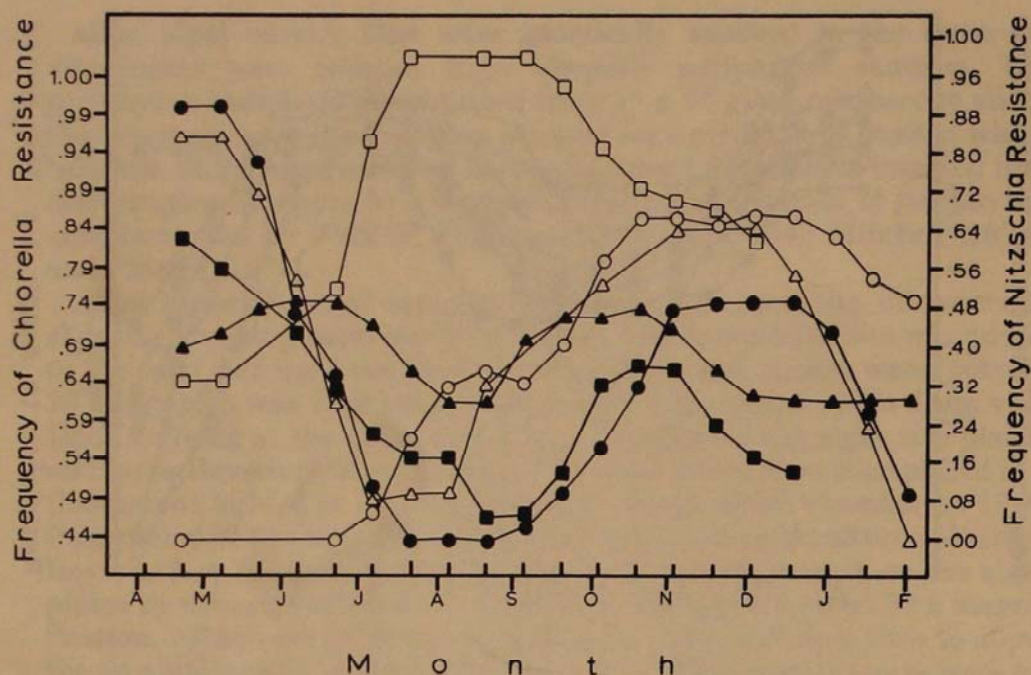
FIGURE 2. Biweekly gene frequencies for resistance to tetracycline•HC1, for isolates of *Chlorella* (black symbols) and *Nitzschia* (open symbols) that were isolated from artificial substrates within three environments (triangles = stressed, circles = nonstressed, and squares = Ohio River).

0.84 to 0.00). There was a decrease in the frequency from spring until late summer at which time an increase until late-fall/early-winter where there was again a decrease in resistance until February when the *Nitzschia* isolated from the stressed environment were no longer resistant to tetracycline.

The *Chlorella* isolated from the nonstressed environments (circles in Figure 2) showed a rapid decrease in resistance from spring (c. 0.99) until summer (c. 0.45). At the end of summer there was an increase in frequency, to about 0.68, during late fall and early winter. During winter there was again a decrease in tetracycline resistance in the *Chlorella* from nonstressed environments. A somewhat different pattern of antibiotic resistance was observed for the *Nitzschia* from the nonstressed environments. An increase in resistance beginning in late June and continued until late October where the frequency stabilized with only a slight decline in frequency during the winter months.

The pattern of resistance to ampicillin from algae sampled from these environments (Figure 3) for *Nitzschia* (open symbols) is not the same pattern of resistance found in *Chlorella* isolates from all three environments. *Nitzschia* isolates showed little change in resistance due to the environment from which the algae were isolated. The only exception being a slight decrease in frequency (of less than 10 percent change) that occurred from September to November in the nonstressed environment. The patterns of ampicillin resistance of *Chlorella* were generally similar
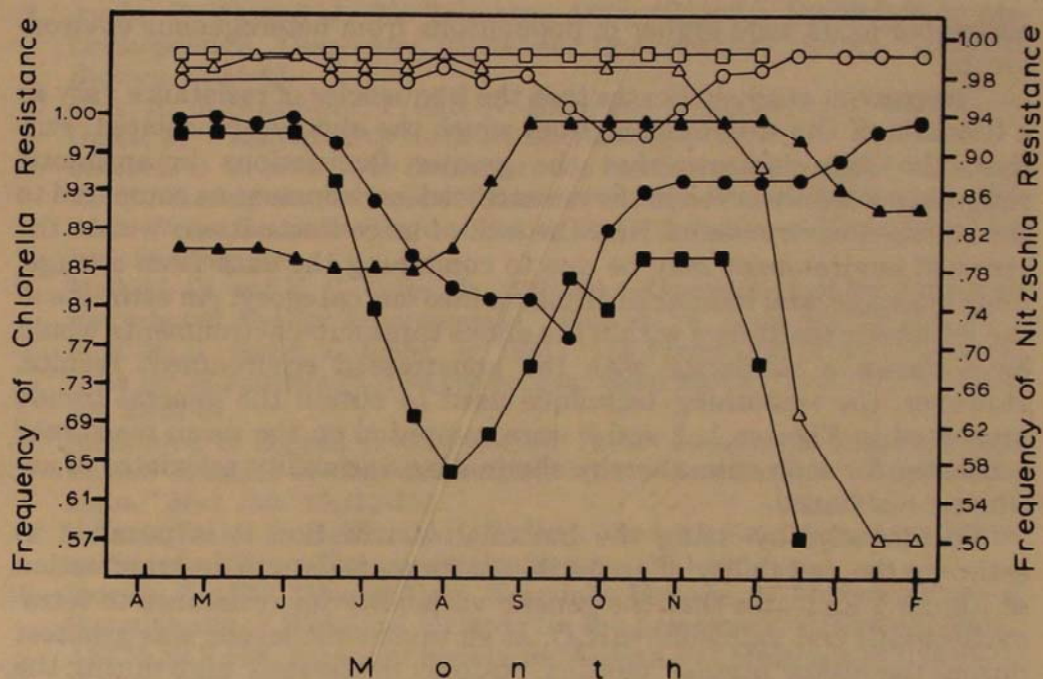
FIGURE 3. Biweekly gene frequencies for resistance to ampicillin•3H$_2$O, for isolates of *Chlorella* (black symbols) and *Nitzschia* (open symbols) that were isolated from artificial substrates within three environments (triangles = stressed, circles = nonstressed, and squares = Ohio River).

to the patterns of tetracycline resistance from the three environments. There was a decrease in ampicillin resistance in isolates from the Ohio River from late spring which continued throughout the summer months. This was followed by an increase through the late fall. There was another decrease in resistance to ampicillin of *Chlorella* isolates from the Ohio River during winter. There was an increase in resistance in *Chlorella* from the stressed environment that occurred from late September through mid-December at which time there was a slight decrease in resistance. The *Chlorella* isolated from the nonstressed environment were almost completely resistant (frequency of 1.0) to ampicillin through mid-June. Then, there was a decrease in resistance until late September. At that time there was a slow increase in ampicillin resistance until the algae were again almost completely resistant to ampicillin.

Discussion

Valentine and Ayala (1976) found that krill species demonstrate higher genetic variability when trophic resources were "less seasonal (more stable)." These authors also stated that only a few genotypes are adaptively favored by "unstable" resources. Schopf and Dutton (1976) have also indicated that gene frequencies in bryozoans are influenced by temperature. Abbott (1976) found that there was more genetic variability in *Senecio vulgaris* from heterogeneous environments (Powell, 1971). In *Drosophila willistoni* the average heterozygosity and the number of

alleles per locus were higher in populations from heterogenous environments.

The present study indicates that the frequencies of resistance vary as a function of the environment from which the algae were isolated. Further, the data indicate that the greater fluctuations in antibiotic resistance were observed in the nonstressed environment as compared to the stressed environment. But, the lack of large fluctuations within the stressed environment may be due to combining the data from sewage, mine drainage, and industrial effluents into one category. An estimate of the antibiotic resistance within the above three sub-environments would have shown a similarity with the nonstressed environment results. However, the smoothing technique used to obtain the general trends presented in Figures 1, 2 and 3 were computed on the mean resistance estimates for each date; thereby eliminating variability estimates of antibiotic resistance.

Fortunately, by using the binomial distribution it is possible to estimate the variability of an antibiotic for each date. A re-examination of Figure 1 indicates that the genetic variability for resistance to tetracycline•HCl and ampicillin•$3H_2O$, at all taxonomic levels, was greatest during the hotter summer months, but only moderately high during the cold winter months. Moll and Keller (1980) indicated that the growth and/or attachment of the algae tended to follow this same seasonal pattern. This leads to the conclusion that the resistance to antibiotics, genetic variability, diversity (ecological) of the attached algae, and water temperature are interrelated. The results of this study (Figure 1) also indicate that the level of variability in response to the genetic markers (ampicillin•$3H_2O$ and tetracycline•HCl) was the same for the species, genus, phyla, and for all of the algae tested. This supports the findings of Ayala and Valentine (1974), using electrophoretic techniques. They reported that the same level of genetic variability existed in similar species of *Ophiomusium lymani* belonging to other classes and phyla. This leads to a general conclusion that organisms within any taxonomic level, from the same environment, tend to have the same level of genetic variation.

The following conclusions are reached: 1) at all algal taxonomic levels there is approximately the same frequency of resistance to genetic markers (antibiotics), 2) there is greater variability in the frequency of resistance to the genetic markers due to environmental differences than due to taxonomic differences, 3) two genera (*Chlorella* and *Nitzschia*) showed different seasonal responses to two genetic markers (tetracycline•HCl) and ampicillin•$3H_2O$), and 4) there were higher frequencies of resistance to the genetic markers from algal isolates from nonstressed environments than algal isolates from stressed environments.

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The Periphyton LC-50 Concentrations for 32 Antibiotics Assayed on Two Algal Media

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Abstract

The growth of 98 unialgal cultures on 32 antibiotics were examined using the replicate plating technique of Murkerjee and Keller (1973) to establish LC-50 con-

centrations for each of 32 antibiotics. The 32 antibiotics were examined on modified Chu No. 14 and on modified Beyerinck media. The Chu media was nonspecific while the Beyerinck media favored the growth of *Chlorella*.

With this in mind, LC-50 concentrations for each of the 32 antibiotics were estimated with six genera (seven species) using four concentrations of each antibiotic. The concentrations used were: 0 μg, 250 μg, 500 μg, 750 μg, and 1000 μg/ml. The LC-50 concentrations were estimated from the resultant data by either probit analysis or by linear regression analysis. The regression analysis was used to estimate the LC-50 concentrations when there was an obvious linear relationship between the dosage of the antibiotic and the growth response by the algae while probit analysis was used for those antibiotics where the dose/response relationship was not obvious. The final LC-50 concentrations of the antibiotics on the Beyerinck medium ranged from 17 to 1214 μg/ml while the LC-50 concentrations of the antibiotics on the Chu medium ranged from 21 to 1250 μg/ml. Analyses of variance of the growth data showed a significant antibiotic by media interaction indicating that certain cultures grew better on one or the other of the media in the presence of certain antibiotics.

Introduction

For many years antibiotics have been used for the isolation and purification of algal cultures (James, 1971). These purification techniques usually involved one or more of the following antibiotics: 1) penicillin "G," 2) streptomycin sulfate, 3) penicillin "K," 4) chloranphenicol, 5) polyanyxin "E," or 6) neomycin. The reason for using these antibiotics is that the algae are relatively tolerant to higher concentrations of these specific antibiotics than are bacteria and fungi (Jones, Rhodes, and Evans, 1973). The antibiotics have also been utilized in the cytological study (involving chromosome and chromatid breaks) of the algae (Vedajanani and Sarma, 1978). Antibiotics have been used in assays examining their mutability on Euglena, blue-green algae, and other organisms (Diamond and Schiff, 1974; Yopp, Albright, and Miller, 1979; and Daum and Lemke, 1979). In addition, many plants have been found to vary in their resistance to antibiotics (Jones, et al., 1973 and Futer, et al., 1953).

It is this genetic variability in antibiotic resistance that is of interest in the investigation of the algae reported in this paper. If a genetic technique could be developed that would allow for the rapid, accurate, and easy assay of algal cultures, it would be far superior to the long and difficult electrophoretic analysis presently required to generate genetic profiles of the algae. Murkerjee and Keller (1973) developed a replicate technique that was used to simultaneously assay 115 physiological and/or biochemical mutants of the unicellular algae *Chlorella*. Therefore, by applying this replicate plating technique to assay a large number of algal cultures on different antibiotic plates one would have a method that would be superior to electrophoretic methods of estimating algal genetic profiles.

Materials and Methods

Two experiments were used to determine the effectiveness of the antibiotic/algal replicate plating technique. The first experiment involved estimating the LC-50 concentrations (those concentration of antibiotic where an estimated 50% of the cultures would grow) on 32 antibiotics that were presumptive growth inhibitors of algae. The second experiment was completed in order to determine if there was a difference between two algal media in utilizing this antibiotic scoring technique. In the first experiment 96 unialgal cultures were isolated from a small, clear stream (Darnell Run) five miles north of Morgantown, West Virginia. These 96 cultures contained the seven species of algae listed in Table 3. In addition to these field cultures, two laboratory cultures of *Chlorella vulgaris* were also utilized in the first experiment. Therefore, the total of 98 field and laboratory cultures were maintained at room temperature (20°-23°C) under two 40 watt cool white fluorescent lights (505 lux) for a period of approximately 60 days. This length of time was needed to allow the populations within the cultures to grow to a large enough size for use in inoculating the plates containing the antibiotic algal medium.

The plates containing the antibiotic medium were prepared by adding 2 g of noble agar (Difco) to 90 mls of the modified Beyerinck or the Modified Chu media. Simultaneously, 10 mls of distilled water was added to 0, 250, 500, 750, or 1000 micrograms of a specific antibiotic. Once the antibiotic was dissolved in the 10 ml solution it was passed thru a 0.45 micron millipore filter into a sterile flask. The now soluble and sterile antibiotic was added to the previously sterilized algal media. The resulting solution was slowly shaken and then poured into three replicate sterile plastic petri dishes. The petri dishes containing a specific antibiotic dissolved in either Beyerinck or Chu media was then allowed to harden.

The 98 unialgal cultures were simultaneously plated on each of five concentrations for the three replicate plates for each of the 32 antibiotics on each of the two algal media using the replication technique of Murkerjee and Keller (1973). Thus a total of 960 plates, each containing the innocula from the 98 independent unialgal cultures formed a total of 94,080 observations. These plates were then placed in a constant temperature room at 18°C under a 24-hour light cycle (with a 40 watt fluorescent light, 301 lux) for a period of 21 days. At the end of the 21 days a Bausch and Lomb dissecting microscope was used to score (0 = no growth and 1 = growth) the growth of the algae. The resulting data for all 98 unialgal cultures on each of the 32 antibiotics was then analyzed using either a linear regression or a probit analysis to estimate the algal LC-50 concentration of a specific antibiotic.

In the second experiment, the previously established LC-50 concentrations for each of the 32 antibiotics were used to prepare the fresh Beyerinck and Chu media. The 98 unialgal cultures were then inoculated on three replicate plates of either Beyerinck or Chu media, containing the LC-50 concentration for each of the 32 antibiotics. This resulted in a total of 192 plates each containing 98 individual unialgal cultures for a

total of 18,816 observations. These plates were then placed in a constant temperature chamber at 18°C under 24 hours of continuous 40 watt fluorescent light (301 lux) for a period of 21 days. On the 22nd day, these cultures were assayed using the 1-6 scoring system described in Table 1. The resulting data were examined using an analysis of variance (ANOVA) of the two algal media and the 32 antibiotic markers for the seven species of algae tested.

Table 1. The multinomial colony scoring system utilized in assaying the algal growth response (after Canary, 1980)

Scale	Representation	Description
1	○	No growth*
2	◉	Very poor growth, spotty growth
3	◐	Poor growth, patches of growth
4	●	Growth, not a complete circle of growth
5	●	Good growth, solid circle of growth
6	●	Very good growth, raised solid circle of growth

*E.g., the outline of water/inoculum is only faintly visible—absence of algae.

Results

The final algal LC-50 concentrations for each antibiotic on either Beyerinck or Chu media for all 98 unialgal cultures is presented in Table 2. For a majority of antibiotics, there was a difference in the amount of antibiotic needed to produce the LC-50 concentration on either the Beyerinck or the Chu media. The laboratory cultures of *Chlorella vulgaris* (which have been in the laboratory for some ten years) showed a similar amount of variability in growth response to the various concentration of each of the antibiotics as did the field cultures of *Chlorella vulgaris*.

The analysis of variance for the 98 unialgal cultures composing the seven algal species on the two media for each of the 32 antibiotics is presented in Table 3.

A major concern, in this paper, is the fact that all seven species of algae showed a significant media by antibiotic interaction effect, thereby indicating that significant, but inconsistent growth responses of the algae occurred between the two media and the 32 antibiotic examinations. For example, *C. vulgaris* grew better on Beyerinck media containing ampicillin than on Chu media containing ampicillin. Also, *C. vulgaris* grew better on Chu media containing tetracycline than on Beyerinck media containing tetracycline.

Discussion

The estimated algal LC-50 concentrations (Table 2) of a particular antibiotic (based upon the 98 unialgal cultures) and a particular medium in-

Table 2. The estimated LC-50 concentration (micrograms/ml) based upon 98 unialgal cultures composing seven species of algae listed in Table 3 for each antibiotic on each algal medium (Beyerinck or Chu No. 14)

Antibiotic	Beyerinck Media	Chu Media
Ampicillin	176	1250**
Ampicillin trihydrate	309	125
Ancobon	252	101
Aureomycin*	146	26
BB-K8 base	61	315
Carbenicillin indanylsulfate	30	122
Cefazolin	37	190
Cefazolin sodium	523	146
Cephapirin sodium	517	410
Cephaloglycin*	1059**	121
Cephloridine	503	851
Cephradine	125	125
Chloroaphenicol	66	506
Cycloserine	312	248
Declomycin	138	29
Deoxycycline	59	30
Erythromycin base	1025**	187
Erythromycin estolate	659	590
Erythromycin stearate	237	61
Kanamycin sulfate	114	243
Lincomycin hydrochloride	119	300
Minocin	69	21
Nystatin*	268	277
Oleandomycin phosphate	1214**	125
Oxytetracycline hydrochloride*	49	180
Paromysin sulfate	312	305
Penicillin potassium	235	233
Sulfisoxazole	17	99
Tetracycline hydrochloride	102	124
Troleandomycin*	125	417
Tobramycin	176	32
Vancomycin hydrochloride	1195**	124

*These antibiotics were dissolved in 9 mls of algal media to which 0.5 ml of 1 normal hydrochloric acid was added prior to sterilization. Following the sterilization of the media by the use of a 0.45 millipore filter, the media containing the antibiotic, was neutralized by adding 0.5 ml of a 1 normal sodium hydroxide solution. Then the remaining 90 mls of sterile nutrient media was added.

**LC-50 concentrations estimated (beyond concentrations used in the study) from probit or regression analyses.

Table 3. Analysis of variance of the two algal media and the 32 genetic (antibiotic) markers using the multinomial scoring system shown in Table 1

Test Organisms	Media	Antibiotic	Media Antibiotic Interaction
Chlorella ellipsodia	*	*	**
Chlorella vulgaris	N.S.	N.S.	**
Oscilatoria limnetica	**	N.S.	**
Chlocococcum sp.	*	*	*
Gomphonema sp.	**	*	**
Nitzschia sp.	N.S.	N.S.	**
Scenedesmus sp.	**	*	**

N.S. = Not significant at the .05 level.
* = Significant at the .05 level.
** = Significant at the .01 level.

dicates that the genetic control of the algal growth responses are sensitive to the joint effects of the type of medium and the specific antibiotic examined. The ANOVA's (Table 3) showed that all species of algae examined showed significant interaction responses of a particular antibiotic with a specific media. A similar response pattern has been shown in an experiment concerning *E. coli* and *S. typhimurium* where Mattoni, et al. (1978), showed differential growth responses to the interaction of two specific stresses (vibration and irradiation) under which these organisms were tested. The observation that these algal species show this differential response to the two substrates was reported in two other studies. One study involved exposing diatoms to combinations of sea water and an antibiotic produced by *S. aureus* (Aubert and Pesando, 1969) where they found that the antibiotic resistance of the phytoplankton responded to changes in the physical environment. The second study involved testing the response of *Chlorella* from three test environments which was reflected by growth or no growth responses due to genetic differences (Canary and Keller, 1978). These authors found long-term environmental selection was the critical factor affecting the genetic control of the algae. Thus, this present work as well as the work of others would indicate that an algal or bacterial species possesses the breadth of genetic variability that is able to respond in several ways to the various substrates and the changes in the environment to which it is exposed. Further, that the genetic "response" system is sensitive to the interactive effects of the environmental and test regimes.

The analysis of variance of the growth responses of the seven species of algae presented in Table 3 used a 1-6 scoring scale to estimate growth. A simpler method of estimating this growth response would be to use a binomial scale of no growth and growth. The advantage of using the latter scoring system is that it allows the estimation of the Hardy-Weinberg parameters p and q (where p would be the resistance to the

antibiotic tested). Canary (1980) utilized this approach in estimating the response of algae from various aquatic environments with varying types and degrees of pollution. Also, an algal plating technique was used by Chan, et al. (1980), to estimate the allelopathy in certain marine micro-algae. By estimating the combined genetic response (using either the binomial scale or the 1-6 multinomial scale) of the 32 individual anti-biotics it is possible to elaborate a genetic resistance profile of the algae so examined. Therefore, this *in vivo* antibiotic technique either alone, or in conjunction with electrophoretic techniques, can be utilized to describe the genetic profile of an algae that was a function of the environ-ment from which it was isolated and within which the alga evolved.

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Additions to the Vascular Plant
Flora of West Virginia

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Abstract

During the past year, ten new species of vascular plants have been identified or verified at the West Virginia University Herbarium as new records for the state of West Virginia.

The new species here reported are:

Paspalum pubiflorum Rupr., Tyler County (*Dennis Bittinger* 151) August 14, 1979. (A southern species occasionally found in our range.)

Panicum bicknellii Nash, Upshur County (*Earl E. Berkley* s.n.) June 4, 1929. (In our range. To be expected.)

Stenanthium gramineum (Ker) Morong var. *micranthum* Fern., Barbour County (*John Findley* s.n.) August 5, 1967; Pendleton County (*John L. Smith* s.n.) August 13, 1967; Pendleton County (*Eugene E. Hutton* s.n.) August 10, 1972. (A species to our immediate south. To be expected.)

Polygonum perfoliatum L., Mineral County (*Earl M. Whetsel* s.n.) September 1980. (Adventive from Asia.)

Ranunculus pensylvanicus L. f., Pocahontas County (*William N. Grafton* and *Osbra Eye* s.n.) August 16, 1976 and Pocahontas County (*Osbra Eye* s.n.) July 13, 1980. (In our range. To be expected.)

Aquileqia vulgaris L., Preston County (*A. D. Hopkins* s.n.) June 24, 1897; Pendleton County (*Floyd Bartley* s.n.) June 11, 1969; Fayette County (*William N. Grafton* s.n.) May 28, 1972; Hardy County (*Eugene E. Hutton* s.n.) June 18, 1977; Mineral County (*William N. Grafton* s.n. and *Allen Miller*) May 24, 1970. (Introduced from Europe.)

Cardaria draba (L.) Desv., Randolph County (*Eugene E. Hutton* s.n.) May 23, 1978 and May 11, 1978 and May 11, 1979. (Naturalized from Europe. A troublesome weed.)

Chorispora tenella (Willd.) DC., Mason County (*Claire Stuart* s.n.) April 30, 1980. (Adventive from Asia.)

Rhus toxicodendron L. Kanawha County (*Ellen Thomas* and *John Delfino* s.n.) May 25, 1979. (Primarily a coastal plains species. Occasionally found farther inland.)

Aster novi-belgii L. Randolph County (*Eugene E. Hutton* s.n.) September 4, 1979. (Primarily a coastal plains species. Occasionally found farther inland.)

Geology and Mining Section

An edrioasteroid from the Foreknobs Formation (Upper Devonian) of West Virginia

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Abstract

The edrioasteroid species *Cooperidiscus alleganius* (Clarke) was originally described in 1901 from a small number of specimens from the Upper Devonian of northwestern Pennsylvania and southwestern New York. An unusually complete specimen from the Foreknobs Formation of the Greenland Gap Group near Elkins, West Virginia, extends the geographical range of this species and provides information on the structure of the aboral surface of the theca, which is seen to be fully plated.

The edrioasteroids are a small but diverse group of echinoderms, known from the Lower Cambrian through Pennsylvanian and including five morphologically distinct types of thecal construction. Generally they have domal or clavate thecae although some are globoid and others axially elongate. Edrioasteroids are not common fossils, though entire populations have been preserved when the right conditions for fossilization occurred. It appears that preservation normally depends on catastrophic kills, most resulting from storm-deposited mud burying the entire substrate surface area (Bell, 1980). The discovery of a specimen of *Cooperidiscus alleganius* (Clarke) in the Foreknobs Formation of the Greenland Gap Group near Elkins, West Virginia, is therefore worth noting because of the rarity of the group and the fact that this genus has not previously been reported from West Virginia. However, this specimen is also sufficiently well preserved to provide additional information on the aboral surface of the theca, otherwise imperfectly known.

The specimen is a particularly well preserved theca and was found by the author in April, 1980. It came from a roadcut on Route 33 at its intersection with the Kelly Mountain Road, approximately six miles east of Elkins, West Virginia. The exposures here represent the base of the Foreknobs Formation of the Greenland Gap Group (previously termed the Chemung Sandstone), the age of which is probably upper Frasnian or lower Famennian (J. Schwietering pers. comm.). The specimen came from a fallen slab of grey/brown sandstone containing clasts of grey shale at the base and including plant fragments and numerous limonitic nodules. A small brachiopod replaced by limonite was found in association with the edrioasteroid but no other fossils could be identified.
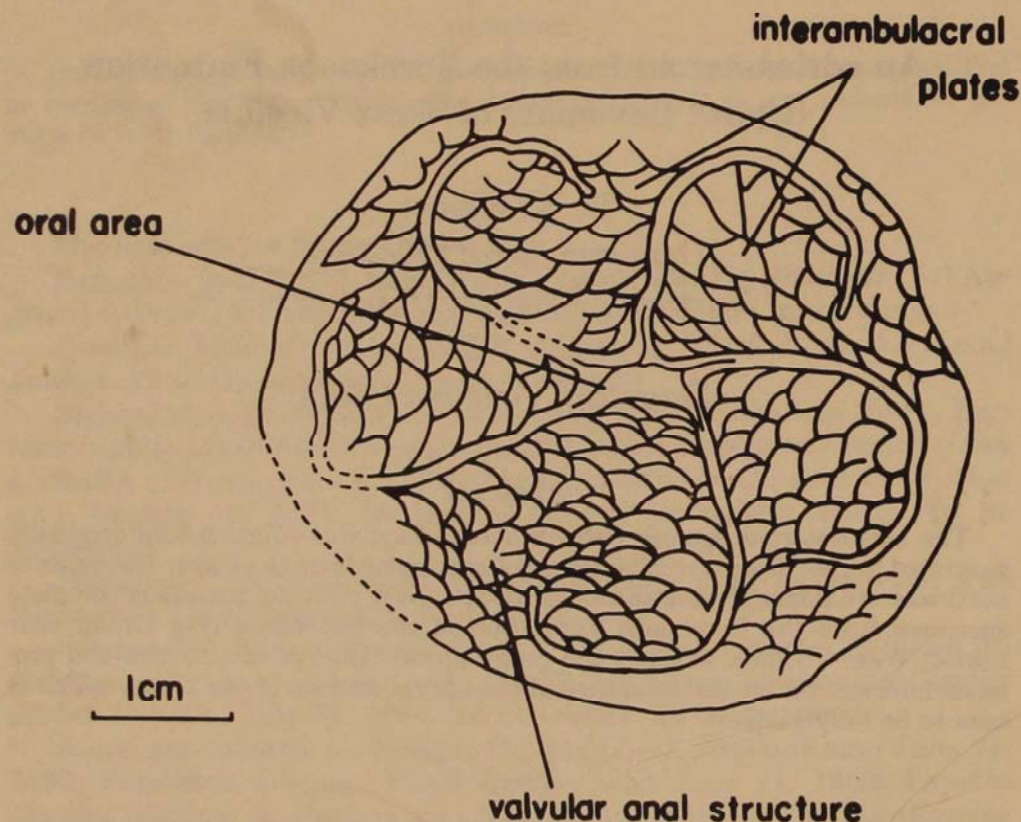
FIGURE 1. Oral surface of *Cooperidiscus alleganius*.

The test of the edrioasteroid had also been replaced by limonite and this was removed mechanically to expose the ventral and dorsal surfaces of the specimen preserved as natural external moulds in the sandstone. These surfaces were then cast in latex and the pulls were studied after coating with a thin sublimate of ammonium chloride.

Description

The upper, oral, surface of the theca is convex upward and includes the oral-ambulacral structures, hydropore, anal area and inter-

1cm
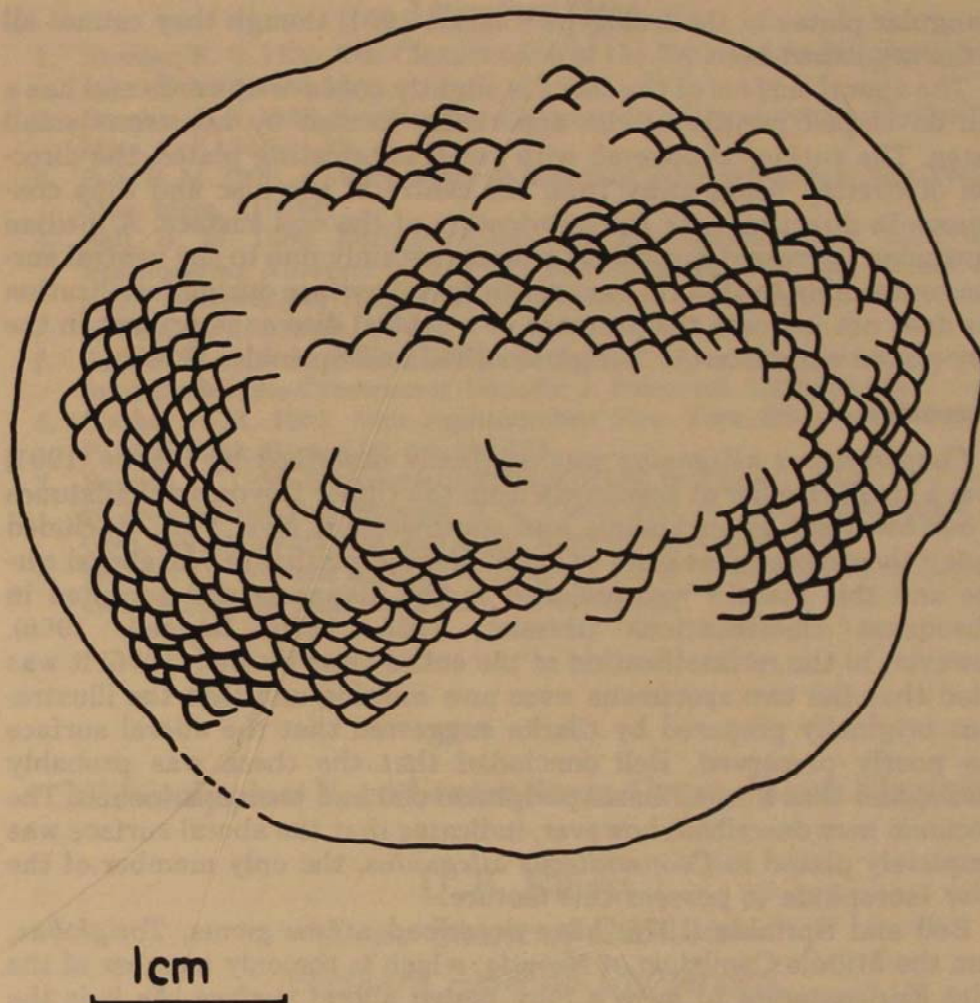
FIGURE 2. Aboral surface of *Cooperidiscus alleganius* showing surface of small imbricating plates.

ambulacral plates. The axial diameter is 51.5 mm, the transverse diameter 44.5 mm which is slightly larger than any previously described specimen of this species, otherwise it agrees in all features with representatives of *Cooperidiscus alleganius* described by Clarke (1901) from the Upper Devonian Chemung Sandstone from southwestern New York and northeastern Pennsylvania.

In previously described specimens the central oral rise comprises a transversely elongate oral region composed of numerous small plates though the preservation is not good enough to allow them to be differentiated in this case. The ambulacra are long and extremely narrow, in proportion to the thecal diameter they appear to be half as wide as the ambulacra of any other known edrioasteroid (Bell, 1976). The interambulacra are wide and covered by numerous plates which are imbricated towards the mouth, a feature accentuated by the post-mortem flattening of this specimen. The valvular anal structure consists of ten large

triangular plates in the lectotype (Clarke, 1901) though they cannot all be distinguished here.

The aboral surface of the theca is slightly concave upwards and has a well developed peripheral rim apparently formed by numerous small plates. The surface is covered with small imbricating plates, the direction of overlap being away from the centre of the disc and thus continuous in direction with the imbrication of the oral surface. A median depression is present but this is almost certainly due to the ventral surface conforming to the oral part of the dorsal surface during fossilization and does not indicate the presence of a central disc as is present in the fully plated edrioasteroid *Totiglobus* (Bell and Sprinkle, 1978).

Discussion

Cooperidiscus alleganius was originally described by Clarke (1901) from a small number of specimens from the Upper Devonian sandstones of northwestern Pennsylvania and southwestern New York. Included among these specimens were two that showed plating on the aboral surface and this feature was included in the diagnosis and accepted in subsequent classifications (Bassler, 1935, 1936; Regnell, 1966). However, in the reclassification of the entire class by Bell (1976) it was noted that the two specimens were now missing and that the illustrations originally prepared by Clarke suggested that the aboral surface was poorly preserved. Bell concluded that the theca was probably clavate and that a small basal peripheral rim had been overlooked. The specimen here described, however, indicates that the aboral surface was completely plated in *Cooperidiscus alleganius*, the only member of the order Isorophida to possess this feature.

Bell and Sprinkle (1978) have described a new genus, *Totiglobus*, from the Middle Cambrian of Nevada, which is the only member of the order Edrioasterida to have a fully plated aboral surface. As it is the earliest member of the order they have suggested that a fully plated aboral surface is a primitive feature and also that the isorophids may have evolved from the edrioasterids or possibly from a common ancestor. Though this suggestion was based on the assumption that the isorophids were clavate and that an evolutionary progression from an attachment disc to a peripheral rim could be traced, the fully plated theca in *Cooperidiscus alleganius* would also tend to substantiate this relationship.

Most edrioasteroids were attached by a peripheral rim and, as they were not plated aborally, incorporated the underlying substrate as part of their protective enclosure. *Cooperidiscus alleganius* appears to have lived on soft sediment, attached by the peripheral rim but with the plated aboral surface possibly giving added protection in the event of being upset by storm currents.

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Mississippian Vertebrates from Greer, West Virginia

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Abstract

New excavations in the Quarry at Greer, Monongalia County, West Virginia, have exposed fresh outcrops of the Bluefield Formation at the base of the Mauch Chunk Group which has previously yielded well preserved vertebrates of Upper Mississippian age. Collecting by members of the West Virginia Geological and Economic Survey and West Virginia University Geology and Geography Department has yielded disarticulated material from the amphibians *Greererpeton burkemorani* and *Proterogyrinus scheelei* together with the remains of dipnoans,

crossopterygians and acanthodians. The diverse and disarticulated nature of this material and the worn condition of some of the bone suggests that the accumulation may have formed as a lag deposit with considerable transport of some elements.

The Greer Limestone quarry at Greer, Monongalia County, West Virginia, is excavated in the Greenbrier Limestone of Upper Mississippian age. The overlying sequence, also exposed in the quarry is the Mauch Chunk Group and from the lowest part of this group, the Bickett Shale Member of the Bluefield Formation, fossil vertebrates were excavated by J. Burke and W. E. Moran of the Cleveland Museum of Natural History in the early 1960's (Barlow, 1969). The most important of these was a labyrinthodont amphibian subsequently described by A. S. Romer (1969) and named *Greererpeton burkemorani*, but another amphibian *Proterogyrinus scheelei* (Romer, 1970) was also discovered together with representatives of several groups of fish; dipnoans, crossopterygians, and acanthodians. The fauna is a significant one, particularly in the case of *Greererpeton burkemorani*, which is the first labyrinthodont amphibian with skull preserved to be described from the Mississippian of North America.

In May 1980 a group of geologists from the Geology and Geography Department at West Virginia University and the West Virginia Geological and Economic Survey visited the quarry with the intention of inspecting the site of the original excavation and collecting any vertebrate material that might have become exposed during the intervening period. In the event the original locality was found to be overgrown and partly obscured by scree, however, it was noted that 200 metres away recent quarrying operations had left a highwall above the Greenbrier Limestone exposing strata of the same horizon as the vertebrate-bearing beds in the original excavation. Inspection of the highwall yielded vertebrate material in-situ in the lower part of the section approximately 1 metre above the top of the Greenbrier Limestone, the sequence at this level consisting of olive green and maroon shale and claystone, overlain by buff to tan slightly silty claystone with maroon streaks. The vertebrate material consisted principally of two large slabs 640 mm X 316 mm which formed part and counterpart, the original slab having broken through the vertebrate horizon. Three smaller slabs also contained bone material, but this was sparse and less well preserved. The material was collected and removed to the Geology and Geography Department at West Virginia University for further preparation. The material on the principal slabs was exposed on one bedding plane and consisted of an accumulation of bones, plates, spines and scales from a variety of vertebrates, these were randomly orientated and showed varying degrees of abrasion and breakage. This material was developed mechanically, matrix being chiselled away from the bones to expose them, after which they were impregnated with a hardening agent formed by dissolving polystyrene in toluene.

FIGURE 1. Part (A) and counterpart (B) of slab from Greer Quarry showing vertebrate material. Key to elements present. Element from ? large rhachitome, e. *Gyracanthus:* g, fin spine. *Greererpeton burkemorani:* ga, articular; gd, dentary; gf, femur; gfi, fibula; gi, intercentrum; gil, ilium; gj, jugal; gr, rib; gs, skull plate; gt, tibia; p, post-frontal. *Proterogyrinus scheelei:* pf, femur; ps, scapulocoracoid. *Rhizodus:* rs, scale; rt, tooth. *Tranodis castrensis:* tp, pterygoid tooth plate. ? *Uronemus:* u, tooth plate.
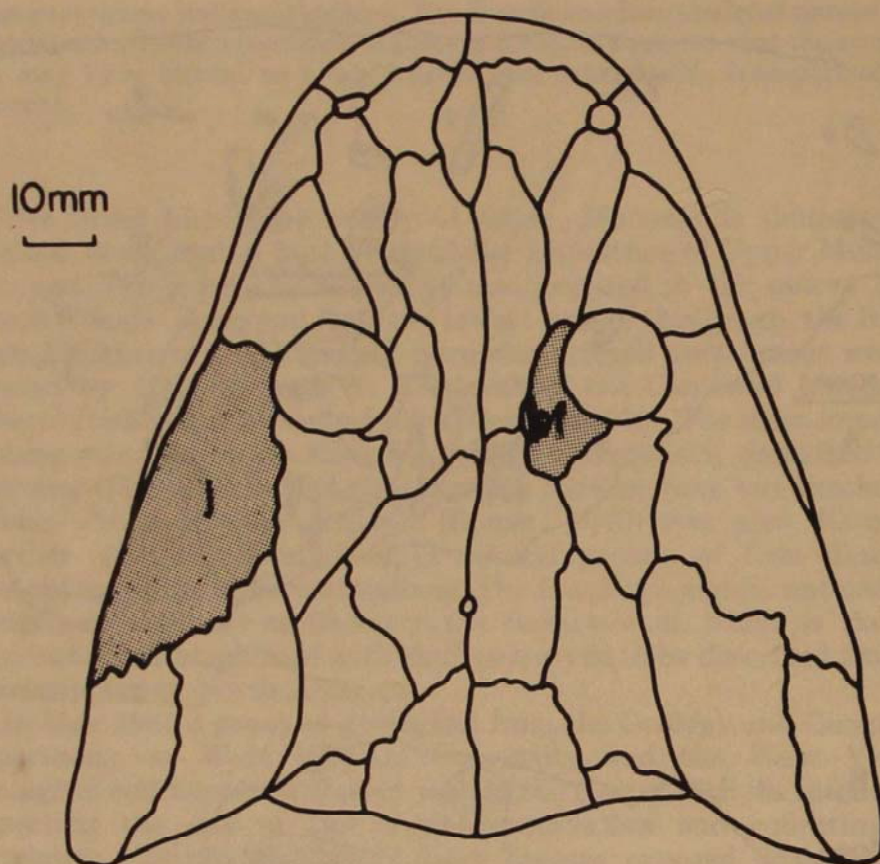
FIGURE 2. Skull roof of *Greererpeton burkemorani* restored after Romer (1969). Stippled elements are those identified in this collection: j. jugal; pf. post-frontal.

Description

Acanthodians—A significant part of the vertebrate material found at the Greer Quarry consists of fin spines which are referred to the acanthodian genus *Gyracanthus*, a name given to spines found in the Mississippian and Pennsylvanian which have an ornament of ridges meeting in a chevron pattern. The spines in this accumulation are slightly curved and oval in cross section with an ornament of tuberculated costae which diverge obliquely down in pairs from the anterior margin. Two morphological variants are present; most of the spines are elongated and slender, up to 97 mm in length, but these are associated with more triangular spines with sparse tuberculation reaching a maximum length of 35 mm. These are probably both from the same species, however the fish is only known from isolated elements and its affinities and structure are largely unknown.

Acanthodians are a group of Palaeozoic jawed fish whose relationships are unclear at present though they appear to be more closely related to bony fish than to the sharks and rays. The characteristic bony spines were inserted in front of the paired and median fins and acted as

cutwaters principally though there is evidence that they could be erected by the operation of muscles and used as a means of defence (Moy-Thomas and Miles, 1971). The group as a whole is found in both fresh-water and marine sediments and it may be that some species were euryhaline, though *Gyracanthus* appears to have been restricted to fresh water.

Dipnoans—Lungfish are a long lived group appearing in the Lower Devonian and continuing to the present day. They are represented in this collection by two tooth plates, one of which is a left pterygoid tooth plate of *Tranodis castrensis* a genus originally described from this locality by Thomson (1965). The tooth plate is triangular; has a maximum length of 20 mm and bears nine radiating rows of teeth.

The other tooth plate is slightly smaller, 17 mm long, but very much more robust in appearance with two rows of large pyramidal teeth. This may represent a form similar to the European form *Uronemus* which is common in tetrapod localities in the Carboniferous.

No other bones or plates could be identified as belonging to this group though it is possible that some of the more worn material could be attributed to it. The group throughout its history has been adapted primarily for life on the bottom, in shallow fresh waters. Modern forms are adapted to breathe air and weather dry periods by burrowing, and it appears that this facility was widely distributed in the group and had already been acquired by the Devonian.

Rhipidistians—Three very large scales and three large teeth are referred to the rhipidistians, a group of large bony fish among whose number lie the ancestors of the amphibians and ultimately all tetrapods. The teeth are smooth and curved, oval in cross section and range in length from 16 mm to 29 mm. The scales are roundly quadrangular, thin, and have a surface sculpture in the form of a network of tubercules and costules. They range in diameter from 30 mm to 34 mm. This form is a member of the Order Rhizodontida and can be attributed to the genus *Rhizodus* as the teeth are laterally compressed. The fish is known only from incomplete remains, however it must have been of very considerable size as jaws up to 1 metre long have been found.

Amphibians—Three amphibians are known from this locality and all three appear to be represented in this collection. The best represented is the labyrinthodont *Greererpeton burkemorani* which was originally described from this locality by A. S. Romer (1969). This was a fairly large animal, the skull of the original specimen is 128 mm long, and the material described here includes disarticulated fragments of the skull and postcranial skeleton.

Cranial remains—These consist of three skull plates, closely associated though not articulated, and three jaw fragments. All the plates exhibit the typical labyrinthodont sculpturing with circular depressions surrounded by ridges near the center of ossification, gradually changing to a series of long ridges with intervening valleys in elements extending some distance from the ossification centers.

One plate is clearly the right post-frontal and is a triangular bone 40

mm in length, broadening posteriorly and showing one concave margin where it forms the upper margin of the orbit. Associated with it is another small plate which has been damaged and cannot be identified with any degree of certainty. The third skull plate is a large left jugal, 75 mm long and 30 mm broad. It is closely associated with the other two bones and the size is compatible with the post-frontal, suggesting that they may have come from the same skull.

The largest jaw fragment is a piece of the jaw ramus 54 mm long, including the articular region and showing the external surface which bears the typical labyrinthodont sculpturing. Two small fragments of the dentary are also present, one is 12 mm long and bears three conical teeth with vertical grooves and a maximum length of 6 mm. The other fragment is longer, 22 mm long, but the four teeth have been broken short though they show the characteristic labyrinthine structure.

Post-cranial remains—A number of elements of the post-cranial skeleton are present comprising parts of the limb girdles and vertebral column. Only part of one intercentrum is present, a stout crescentic element with a diameter of 24 mm, but two ribs can be seen, slender curving bones with a maximum length of 43 mm.

No bones from the pectoral girdle can be identified, but the pelvic girdle is rather better represented. A femur and fibula are closely associated on one slab, and on the other the right ilium is preserved. This is a large bone 63 mm long, with a tall vertical blade and an expanded area which would have been in contact with the ischium.

No skull material of the other amphibian *Proterogyrinus scheelei* (Romer 1970) can be identified, however, a large scapulocoracoid 60 mm long is attributed to this genus because of its size which is twice that of the corresponding bone in *Greererpeton burkemorani*. Also present is what may be a femur, a stout element 66 mm long.

No other bones from this form can be positively identified, as the larger elements are generally in too worn or broken a condition.

One other element is worthy of mention. This is a large bone 144 mm long, curving and expanding from a point at one end to a breadth of 46 mm at the other. The element has been worn and was also damaged when the slab split along the bedding plane during collection. It is certainly too large to be attributable to either *Greererpeton burkemorani* or *Proterogyrinus scheelei*; however, it may be part of a large rhachitome, similar to *Eryops*, that is at present known from this locality only from a few vertebrae.

Discussion

The Bluefield Formation was mostly accumulated under marine conditions, but this was apparently interrupted periodically by seaward encroachment of nearshore mud, sand, and fresh-water marshes (Englund, 1979). All the elements of the fauna described here are fresh-water forms; the rhipidistians and dipnoans are restricted to fresh water, and though the acanthodians are found in a variety of conditions, *Gyracanthus* appears to be restricted to fresh water. The amphibians are also fresh-

water forms, and *Greererpeton burkemorani* was described by Romer (1969) as being primarily a water-dwelling form rather than one leading a truly amphibious existence. The evidence for this being the small limbs which he considered to be incapable of supporting the body and head on any extensive forays onto land, and the system of grooves indicating a functioning lateral line system.

Accumulations of amphibian material have been described from the Permo-Carboniferous and Triassic of Texas (Case 1932, 1935) in which groups of individuals had been preserved in close proximity. In some cases the animals had been overwhelmed by a sudden inrush of coarse sand, in others they had evidently gathered in some small space, possibly the last water of a desiccating pool, before finally perishing. The skeletons in these accumulations were often disarticulated due either to post mortem slumping of the sediment or to the death struggles of the final survivors disturbing cadavers softened by decay.

The material described here is all disarticulated and it is possible that part at least of the *Greererpeton* material may have come from one individual, however it also shows varying degrees of wear. Some of the fin spines and some other large elements have been very much eroded, presumably by transport, while some of the other more fragile elements, particularly the scales of *Rhizodus* which are thin and easily damaged, show no evidence of abrasion. The vertebrate material also occurs in one fairly small location and collecting laterally at the same horizon produced no further material. It therefore seems probable that this accumulation represents a thanatocoenosis, some of the elements having been transported for a considerable distance, while others were derived from nearby.

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Actual Percentage Recovery at the Raccoon Coal Mine, Kanawha County, West Virginia

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Abstract

The choice of a recovery figure for underground coal mining can have a large effect on coal reserve statistics. The most commonly used figure is 50% recovery. Schmidt (1979), however, argues that while there may be 50% recovery in a given mine, real recovery rates over a large area range from 20% to 35%.

In order to test which figure represents a closer approach to what has actually happened, mining records of the Raccoon Mine in the Number 2 Gas seam on Tenmile Fork of Cabin Creek in Kanawha County were examined. Comparing the amount of coal reported to have been mined with the amount available in the area of the mine gives a recovery factor of 33½%. This was checked by measuring the area of the coal mined on the map with a planimeter and comparing the result with the measurement of the amount of coal left unmined yields an actual recovery figure of 31%. Thus the range suggested by Schmidt is closer to what happened at the Raccoon Mine than the more widely used recovery figure of 50%.

Measuring the actual recovery by examining mining records is feasible. By examining more records, a better idea could be obtained of what the actual percentage recovery is.

Introduction

Estimates of the amount of coal available consists of two calculations: (1) an estimate of the amount of coal in place in the ground, and (2) the percentage of that amount which can be recovered and used—that is, the recovery factor. Schmidt (1979) suggested that the commonly used recovery factor for underground mining of 50% is too high. He suggested, instead, that the real recovery factor over large areas for underground mining is between 20% and 35%. Schmidt did not offer empirical validation for his position; rather, he used a line of logical reasoning. This paper is an attempt to test Schmidt's claim empirically by briefly examining previous work on the recovery factor and by measuring a map of an abandoned underground coal mine to determine the percentage of coal available that was actually recovered.

Because of the importance of coal in the economy and the role projected for it in America's "energy future," an accurate recovery figure must be known. If the recovery figure is indeed close to 33% many major policy decisions and corporate decisions are being made on a very questionable assumption based on the extrapolation of the most favorable conditions.

Definition of Recovery Factor

It has been realized for some time that not all coal in place in the ground can be brought to the surface and shipped to the consumer. The phrase "recovery factor" has been used to describe this fact. The definition of the recovery factor is still unsettled, however. Some (for example, Haas, 1923) would base the recovery factor on only those areas where the conditions are such that the mining engineer has full control over recovery. Lowrie (1968) defines three kinds of losses, unavailable coal, economic-technical losses, and unmeasured losses (pillars, spillage, fines, washery refuse). He limited his study to mines or sections of mines and avoids including much unavailable or economic-technical loss coal. Others, such as Schmidt (1979) and Stoek (1923), argue for including a broader range of conditions.

Mining engineers and other coal company officials have a vested interest in showing very high recovery and their reported figures often reflect this. It is more useful from the point of view of knowing the magnitude of energy available to include statistics for a whole coal seam. This paper advocates defining recovery factor in such a way as to be able to determine the amount of coal in the reserve base that can be expected to be economically useful.

Historical Background

Reported recovery figures for the recovery factor tend to follow a pattern of high rates of recovery for small areas and lower rates of recovery for larger areas. Recovery in a well run mine or section of a mine may be very high; however, larger areas may include blocks of coal left unmined for a variety of economic, safety, social, legal, or technical reasons. A mine may be abandoned before all the coal is mined because of a weak coal market. Areas such as roads, navigable rivers, parks, or built up areas may be considered more valuable than the coal underlying them. Land ownership may be so fragmented that assembling a mineable tract may be too difficult. Bad roof conditions or thinning of the coal may lead to areas being left unmined.

Clagett (1923) reports very high figures (72% to 94%) for early mining in the Pocahontas No. 3 seam in a series of mines. Stoek (1923) reports lower figures (41% to 97%) for broader areas in eastern and midwestern coal fields and considers these to be unreliable and too high. Averitt (1969) reports a number of figures from a variety of sources. The average of two large studies which concentrated on mines was about 55%, while the average of seven studies which concentrated on counties or states was about 45%. Trumbull (1957) reports 39% recovery over the whole state of Oklahoma while Dunham and Trumbull (1955) report 50.5% recovery in the Henryetta, Oklahoma mining district.

The most widely used figure, however, is 50%. Averitt (1969), Schroder (1973), and the United States Geological Survey—United States Bureau of Mines classification (USGS, 1976) all use 50% recovery. Recent work (Schmidt, 1979, and van Rensburg, 1980) tends to cast doubt on 50% as being too high.

Plan

The choice of a mine with which to test Schmidt's hypothesis from the thousands of microfilm frames of mine maps available for West Virginia presented a problem. The Raccoon Mine in the Number 2 Gas seam on Tenmile Fork of Cabin Creek in Kanawha County was chosen. Several considerations prompted the choice of the Raccoon Mine: (1) the mine was abandoned, (2) the production history of the mine was known from reports of the West Virginia Department of Mines (WVDM, 1903-1924), (3) a clear and complete map of the mine was available, (4) the mine was small enough for a feasibility study yet large enough that the results would have some validity, (5) independent corroboration of the thickness data reported on the mine map.

The Raccoon Mine operated from 1903 to 1924 as an operation of the Raccoon Fork Coal Company and after 1907 as a unit of the Cabin Creek Consolidated Coal Company. Mining was largely by hand methods.

The mine seems to offer a microcosm of abandoned mined coal lands in West Virginia. Part of the area of the mine was extensively exploited and recovery was good while other parts of the mine were abandoned with apparently recoverable coal still in them. This may have been done for economic reasons. In any case, this parallels the blocks of coal left in

other areas for economic, safety, social, legal or technical reasons. The mine also shows some effects of changing mining technology.

One consideration not dealt with in this preliminary study of one mine is whether changing underground coal mining technology has resulted in a change in the recovery factor. A study by Lowrie (1968) found a correlation between recovery and pillaring system, top conditions, bottom conditions, marketability, thickness, and productivity. No significant correlation was found between method of multiple entry mining (room and pillar systems), types and combinations of mining equipment, annual production, or overburden thickness and recovery. Although these results seem to dampen hopes for a "technological fix" to the problem of percentage recovery, it would be instructive to use mine maps to test the hypothesis that changes in the method of mining coal has led to a higher recovery factor (especially on a regional basis and not on a mine section basis).

Method

A print of the microfilm was made to an arbitrary scale, the largest possible on the equipment. The area of the mine was then measured by a planimeter (the average of 10 readings was used), and the scale factor to convert to acres was found using the mining company grid on the map. The result was 364.6 acres for the mine. The boundaries were determined by allowing for a 200-foot barrier pillar from the edge of the nearest mining or, if the difference were less than 200 feet, by arbitrarily assigning one half the barrier pillar to each mine. The average thickness of coal in the mine was taken as 58½ inches. It was assumed that there were 1,800 tons of coal per acre-foot. This gives an original mineable reserve in the mine of 3,199,365 tons. The Annual Reports of the West Virginia Department of Mines (WVDM, 1903-1924) give the production of the mine as 1,072,416 tons. This was checked by planimetering the total area of the coal left behind, which consists of pillars and all other unmined and abandoned areas, and by planimetering the total area of the coal that was mined.

Results

The recovery factor determined by dividing the reported production by the amount of coal found to be available was 33½%. The recovery factor obtained by measuring the areas of coal mined and coal left in place was 31%. The close agreement of the two figures lends confidence that they represent the percentage of coal extracted.

Of the two figures, the one obtained by comparing the amount of coal in place in the mine with the reported production is probably more accurate. The measurements are simple and quick and can be repeated easily as a check. The process of measuring each pillar left behind is too tedious and time consuming to be repeated. Furthermore, the size of the individual pillars was such that they barely registered on the planimeter. This leads to a large uncertainty in the measurements.

Conclusions

The empirical determination of the recovery factor for underground coal mining in West Virginia has been shown to be feasible. Given the availability of coal mine maps and reports of production of coal, a better determination of the recovery factor should be made. The method of using original resources and reported production would be faster and easier. The method of using areas mined and areas left unmined could be used as an occasional check, however. A number of mines would have to be selected by statistical techniques or by judgement to select mines representative of mining conditions in West Virginia. Without an accurate recovery factor, the amount of useful coal cannot be determined.

The results of this preliminary study indicate that the commonly used recovery factor of 50% is too high when applied to broad areas. If this is true, it has profound implications. Stated simply, there is one sixth less usable coal in West Virginia recoverable by underground mining than the energy experts and policy makers assume.

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Tectonic Fracture Patterns in Northeast Kentucky

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Abstract

Measurements of fracture attitudes of rocks ranging from the Silurian Crab Orchard Formation through the Mississippian Borden Formation and trends of photolineaments in Fleming and Rowan counties, Kentucky, showed prominent trends at N 45°E and N 10°E. The north-east trend is more prevalent in the massive, brittle black shale of the lower portion of the stratigraphic section; the north-south trend is more prevalent in thin sandstone beds floating in plastic shales in the Borden Formation which is the upper portion of the stratigraphic section. Two possible hypotheses are offered: (1) two tectonic deformational episodes, the first occurring after Sunbury deposition and before Borden, and the second occurring post-Borden; (2) two post-Borden tectonic episodes, the first strong enough to fracture only the brittle black shales, the second strong enough to fracture the cushioned sandstones of the Borden Formation. Because both orientation patterns appear in both portions of the stratigraphic sequence, the second hypothesis is more likely; however, fractures could have migrated upwards, thus imprinting pre-existing patterns on the upper part of the sequence. The two tectonic pulses are probably related to the growth of the Appalachian orogen and relate to the formation of the Southern Appalachians and Central Appalachians.

Introduction

An investigation of patterns of natural rock fractures is currently being conducted in the outcrop belt of Silurian through Mississippian rocks of Bath, Fleming, Menifee, and Rowan counties in northeast Kentucky. Rocks ranging from the Silurian Crab Orchard Formation through the Mississippian Borden Formation are being measured. The results reported here are preliminary; they are based on data from outcrops in Fleming and Rowan counties shown in figure 1. Data consist of measurements of orientations of individual fractures, and spacing between adjacent fractures of the same orientation; only the orientation data are used in the analysis in this report. Additional data were derived from photolineament maps.
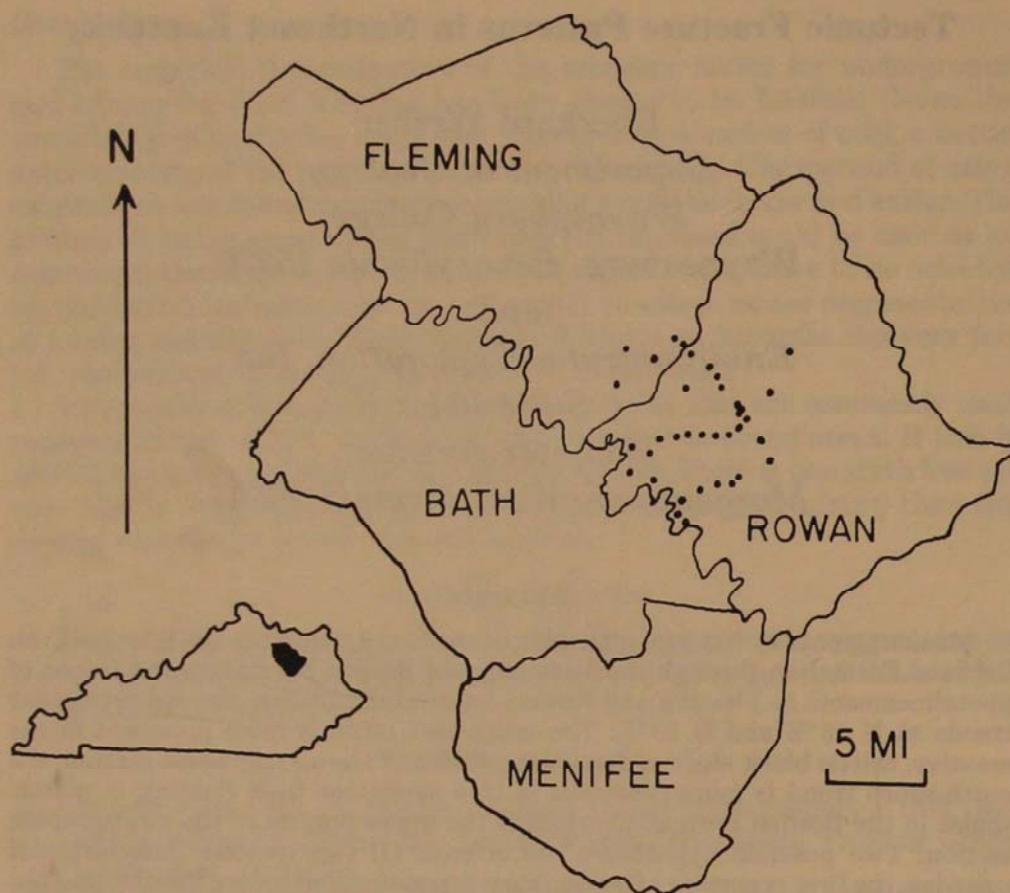
FIGURE 1. Index map showing Bath, Fleming, Menifee, and Rowan counties in northeastern Kentucky. Dots in Fleming and Rowan counties are locations of outcrops measured for this study.

Long (1979) investigated natural rock fracture patterns throughout eastern Kentucky; in the area of the present investigation, he measured fractures on one outcrop per 7½′ topographic quadrangle. His analysis generally did not consider the stratigraphic position of the outcrop; rather, he grouped his data on the basis of lithology, with the exception of the Devonian shales which were treated separately. Long found variations in the areal pattern of fracture trends over the region. In the present study, fracture trends were analyzed for variations through the stratigraphic column in a relatively small area.

Geology of the Study Area

The area under discussion is within the Interior Low Plateaus geologic province. The rocks generally dip very gently to the southeast. There are several structural elements in or near the study area (figure 2). The north-south trending Cincinnati Arch, 50 mi. to the west, is responsible for the regional eastward dip. The axis of the problematical north-south trending Waverly Arch, on the eastern edge of the area, does not appear to significantly affect the dip, but was apparently a relatively
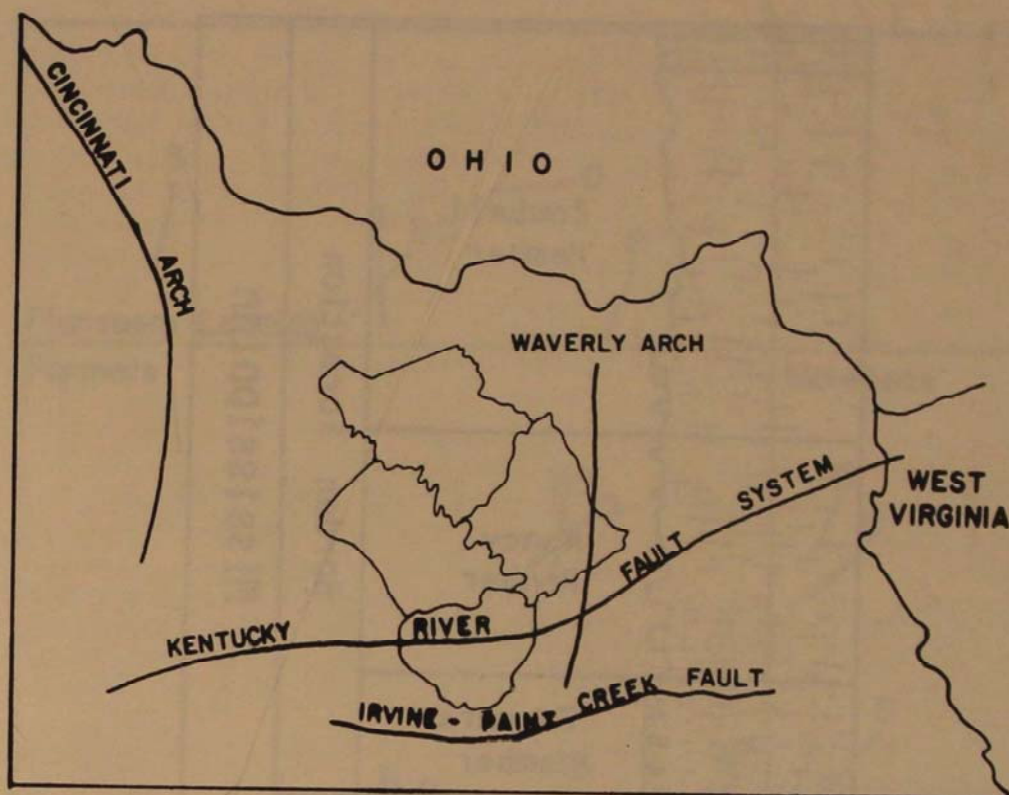
FIGURE 2. Location of structural elements in relation to the study area (adapted from Dever and others, 1977).

positive area during deposition of the rocks, and thus the sedimentary patterns are affected to some extent (Ettensohn, 1979). The only other significant structural elements are the east-west trending vertical faults; one of these, the Kentucky River fault zone, passes through the area.

The outcropping rocks of the area are primarily clastic, with carbonates at the bottom and top of the section under study (figure 3). The environment varied during deposition: shallow water or tidal flat during early Crab Orchard time, rapidly deepening into Ohio time, remaining at least below wave base through the time of deposition of the top of the Cowbell Member of the Borden Formation, and finally returning to shallow water and tidal flat at the end of Borden time.

Results

Measurements were made of the natural fractures (joints) developed in the clastic rocks of the sequence shown in figure 3 at each of the outcrops marked in figure 1. Approximately 750 readings were taken and plotted in orientation diagrams. Several prominent directions, as plotted in figure 4, are evident. The most prominent directions were found to be N 10°E and N 45°E (and ones perpendicular to these), and a direction of about N 70-80°E is of lesser prominence.

One feature of the distribution of the orientations which is noteworthy is the change, at several outcrops, between successive formations. This may be partly seen in figure 4, but it is particularly noticeable at
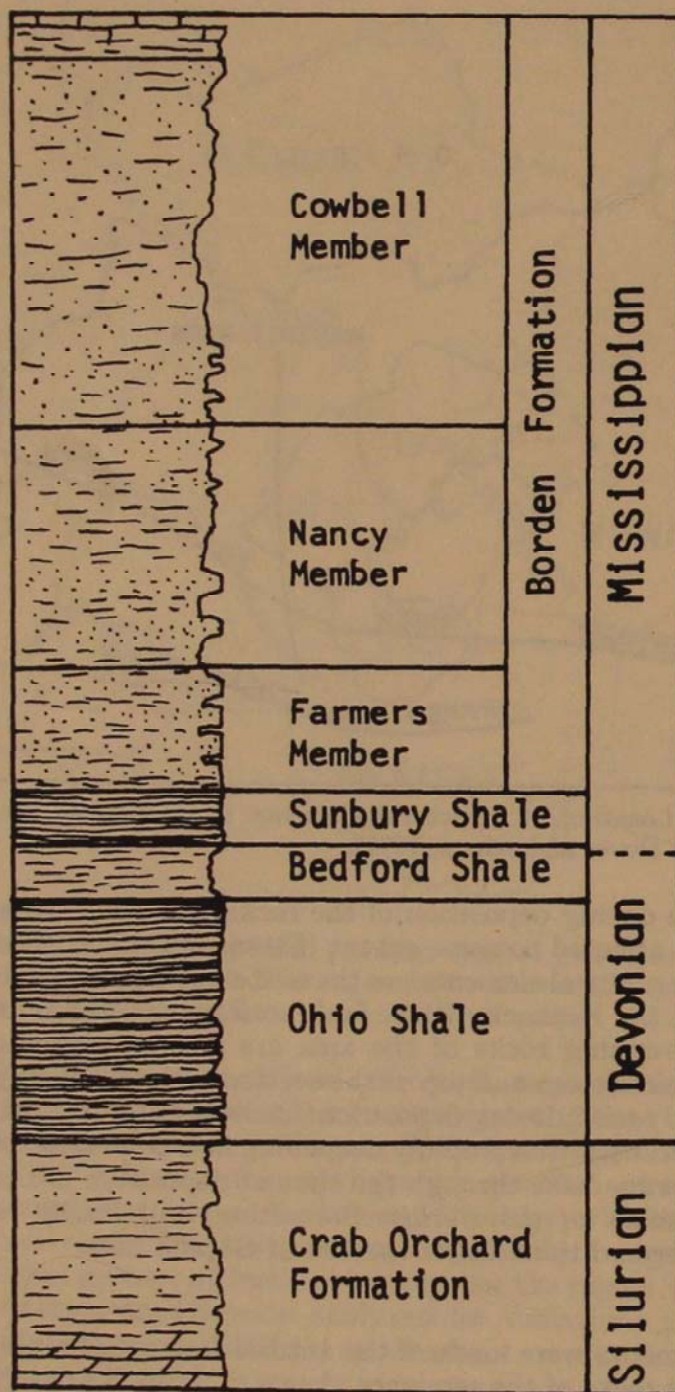
FIGURE 3. Stratigraphic section under study (after McDowell and others, 1971).

some of the outcrops, two of which are detailed in figure 5. At these outcrops, the prominent direction of fracture of the Ohio Shale is approximately N 45°E, but the prominent direction in sandstone beds of the Borden Formation is N 10°E. The fractures in the Sunbury Shale are not consistent between outcrops, they match the trend of the Ohio Shale
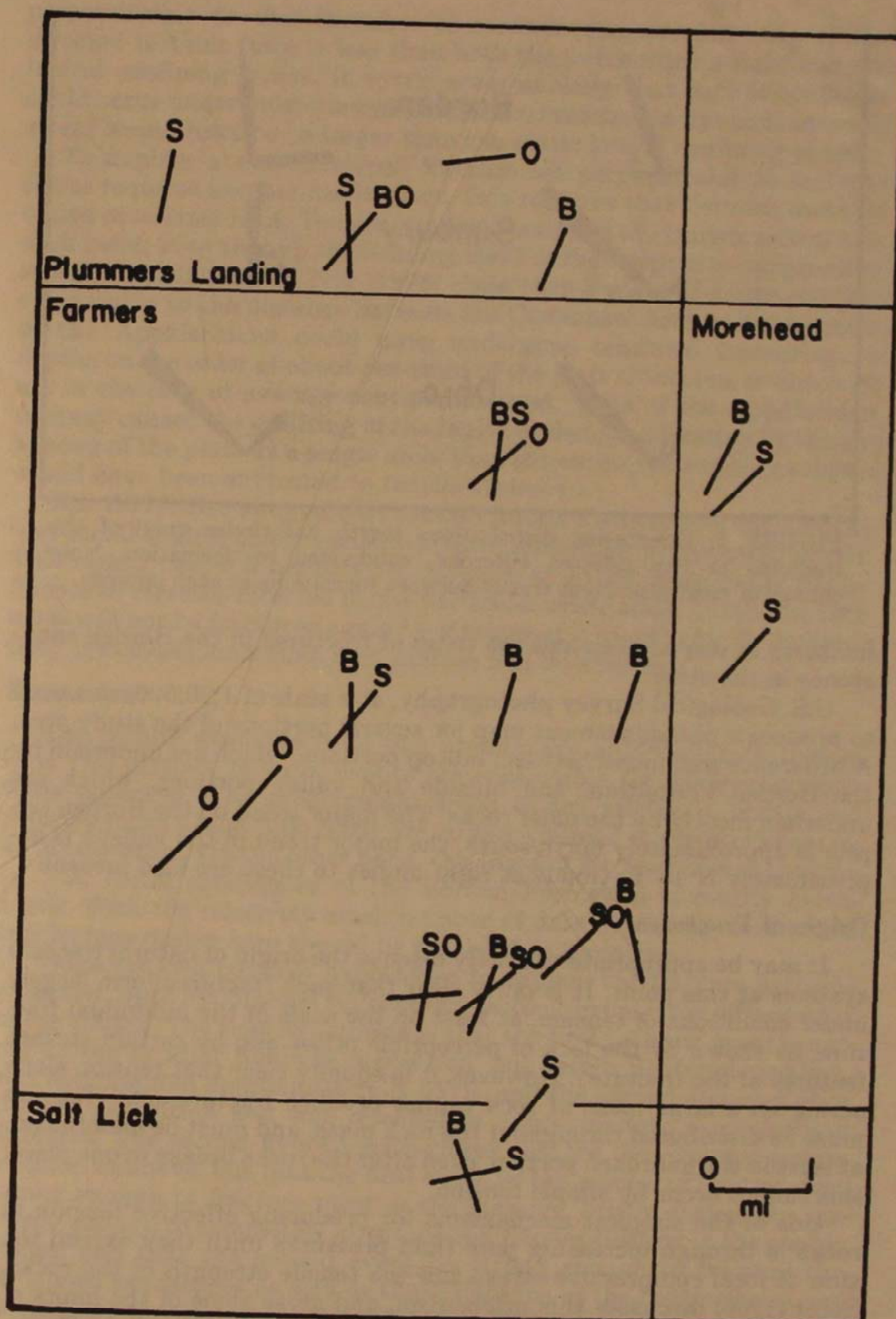
FIGURE 4. Major fracture orientations observed for Borden sandstone beds (B),
Sunbury Shale (S), and Ohio Shale (O) at outcrops in the study area. Only the
more prominent of the orthogonal set pairs is shown. Names shown are those of
the U.S. Geological Survey 7½′ topographic quadrangles.

FIGURE 5. Orientation distributions (north half-circles only) of the fractures at two selected outcrops, subdivided by formation. Note change of most prominent trends between formations at each outcrop.

fractures in one outcrop and the trend of fractures in the Borden sandstones in the other.

U.S. Geological Survey photography, at a scale of 1:30,000, was used to produce a photolineament map for several portions of the study area. A difference was found between hilltop portions, which are underlain by the Borden Formation, and hillside and valley portions, which are underlain mo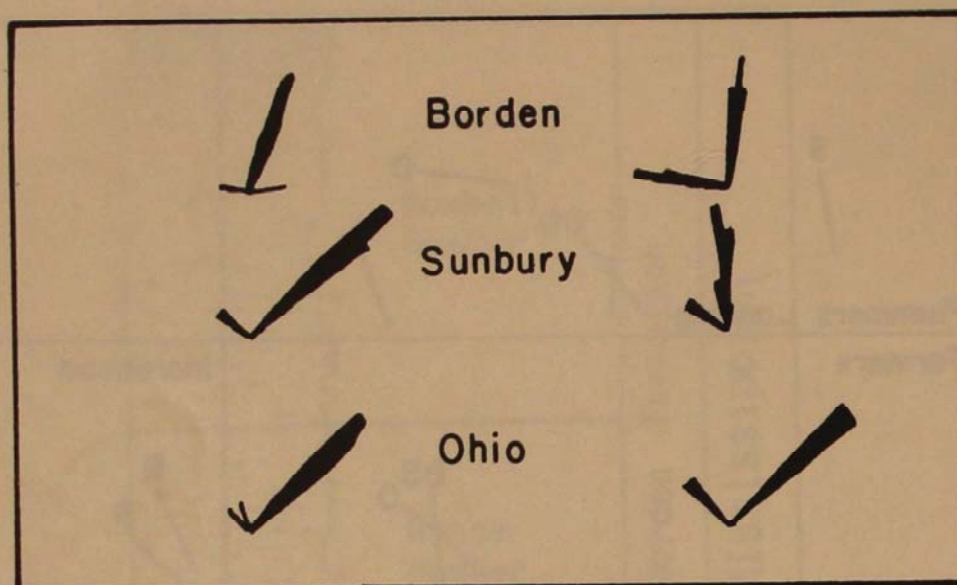stly by the older rocks. The major trend on the Borden terrain is approximately north-south, the major trend in the valleys is approximately N 45°E; trends at right angles to these are also present.

Origin of Fractures

It may be appropriate to briefly discuss the origin of natural fracture systems at this point. It is fairly clear that such fractures form largely under conditions of tension, at least on the scale of the individual fracture, as shown by the lack of perceptible offset and by certain surface features of the fractures. However, it is equally clear that tension alone acting on a large mass of rock cannot produce fracture sets. Tension must be distributed throughout the rock mass, and must be maintained, at least in the unbroken portion, even after the rocks breaks in one place; this cannot occur by simple tension.

One of the simplest mechanisms for producing effective tension in rocks is through increasing pore fluid pressures until they exceed the sum of local compressive stress and the tensile strength of the rocks. Secor (1965) discusses this mechanism, and gives some of the limits of the stress distributions which would still allow "tension" fractures. Generally speaking, within the prescribed limits, fractures may develop

perpendicular to the direction of tectonic compression only if the directed tectonic force is less than both the overburden weight and the lateral confining stress. It would seem unlikely that such a condition could occur under most normal conditions, because the dynamic tectonic stress would have to be larger than the static lateral confining stress.

To explain a well-developed fracture set perpendicular to tectonic stress requires another mechanism. This requires that the rock mass be folded or at least bent. Tensile stress will exist on the convex side of any such bend, even though the bending itself is the result of a compressive stress. Calculations by Nur (1978) show that a plate of a size roughly comparable to the distance between the Cincinnati Arch and the center of the Appalachians could have undergone tensional fracturing to depths on the order of about one-third of the plate thickness, or about 10 mi. in the case of average continental crust. Thus, if the Appalachian orogeny caused the uplifting of the region under consideration by the up-bowing of the plate as a single arch, then the entire sedimentary column would have been subjected to tensile stresses.

Nur (1978) also showed that tension fracture sets cannot intersect at very small angles, unless earlier fractures are welded or cemented closed. This means that if a fracture set develops in a rock mass under the influence of stresses directed in one particular orientation, that same rock mass will not be fractured again by stresses at a small angle to the first. Only previously unbroken rock masses will be affected.

Discussion

The results available from this preliminary study indicate that at least two distinct tectonic events are responsible for the fracture patterns observed. The predominant trend in the relatively brittle and massive rocks of the Ohio Shale are largely oriented in the north-east (N 45°E) direction. On the other hand, the trend of the fractures in the thin (< 3 ft. thick) sandstones of the Borden Formation is mostly north-south. With the relatively small number of data available, most of the conclusions drawn here should be regarded as tentative.

There are two possible hypotheses to explain the fracture patterns observed. Both hypotheses suggest two tectonic events; the difference is in the timing. The first hypothesis is that the first tectonic event occurred during or after Sunbury deposition, but before Borden deposition, and was oriented approximately N 45°E, and the second occurred after Borden deposition and was oriented in approximately a north-south direction. The second hypothesis requires also the two tectonic events oriented as above, but that the first event be the weaker of the two, just strong enough to fracture most of the massive, brittle shales, but not strong enough to completely affect the sandstones floating in the plastic shales; and that the second event be strong enough to fracture the cushioned sandstones as well as those portions of the brittle shales not affected by the first event. The second hypothesis now seems to be the more likely of the two because of the presence of both trends in both portions of the stratigraphic section. The first hypothesis cannot be entirely

ruled out, however, because the trends from the lower rocks could have migrated upwards into the younger rocks.

Identification of the two tectonic events is somewhat speculative; however, the trends seen in the fractures match the trends of the Central Appalachians and the Southern Appalachians reasonably well. If these events indeed caused the fracturing of the rocks in northeastern Kentucky, then the data suggest that the Southern Appalachians are the older of the two. Further work is contemplated which should contribute more data to provide a basis for differentiating any effects of movement along the Kentucky River fault zone from those which may be ascribable to the events producing the Appalachian orogen.

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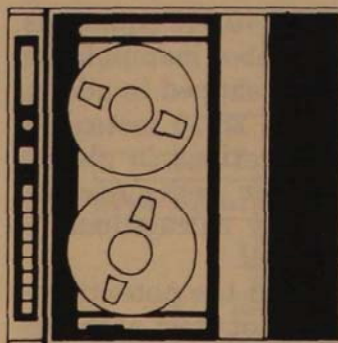
Computer Science Section

Experience with a Small Symbol Manipulation System

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Abstract

This paper describes the capabilities of muSIMP/muMATH 79tm, a symbol manipulation system for microcomputers. The system consists of a number of modules which provide it with the capability of carrying out various mathematical operations. The important thing is that these operations can be performed on expressions as well as numbers. After briefly summarizing the capabilities of the modules, some possible applications are described.

In particular the ability to perform analytical differentiations is used to implement the Post inversion formula for inverting Laplace transforms. The capability of solving linear equations with analytical expressions rather than numbers as coefficients is used to convert the implicit system of differential equations arising in a continuation method for solving a system of nonlinear equations into a more convenient explicit form.

Introduction

The use of computers for symbolic manipulation instead of arithmetic dates back to 1953 when master's theses describing programs for analytical differentiation were accepted at Temple [5] and MIT [9]. There has been considerable progress since then, some of which is summarized in a review paper [4] and two symposia [1,8]. The principal applications have been in fields such as celestial mechanics, general relativity and quantum theory involving very complicated mathematical manipulations. For example, the classic treatise on the motion of the moon [2], which carries out the pertubation to the eight order, took

Delaunay twenty years to prepare and contains about 40,000 equations. In 1970 [3] the analysis was carried out using a symbol manipulation system and only one error was found! Delaunay had slipped in adding three seventh order terms and gave a coefficient as 23/16 instead of 33/16. There have also been some interesting applications in plasma physics where a combination of symbol manipulation and numerical calculations has handled some very difficult stability calculations [6] much more efficiently than either method used by itself.

The scientific community has not fully appreciated the potential of symbol manipulation because of the specialized nature of most of the applications and the limited availability of the systems which required large computers. However, recently a system has been developed which can be implemented on a microcomputer with 48 K of memory and which is relatively easy to use. This paper is based on our experience with the muSIMP/muMATH-79^{tm} package recently acquired by the WVU Department of Aerospace Engineering. Its purpose is to show how the system operates and to present some possible application to engineering analysis.

It should be noted that a new version muMATH 80 has been announced recently which is appreciably faster because it compiles instead of interpreting programs, but the general features apparently are similar. Also a somewhat condensed version is available for the TRS 80 home computer. When students discover how it can be used to do their calculus homework, its use should become widespread.

Description of the System

The system is written in a LISP like language, muSIMP, and consists of a number of modules which provide its mathematical capabilities. The modules are arranged in a hierarchy as shown in Fig. 1. The lower ranking modules cannot be loaded without the higher ranking modules. Because of the limited memory of microcomputers all the modules cannot be loaded simultaneously. It is necessary to prepare an "environment" made up of the modules providing the capabilities needed to handle the particular class of problems. This can be done in two ways. The modules can be loaded directly in the way they are stored on the system disk in a few minutes or they can be condensed as they are loaded to eliminate redundancies which takes about an hour per module. The condensed form takes only about half the memory space as shown in Table 1. The saving in memory is very important as the memory remaining after the program has been loaded not only determines the size of the problem that can be handled but the speed of execution. It is generally necessary during execution to reclaim memory by a "garbage collection" procedure which takes about 1.5 seconds. If this has to be done frequently because there is very little working memory left, then execution will be very slow.

Fortunately it is only necessary to prepare the condensed form of an environment once. It can then be saved on a disk and loaded in a few minutes.
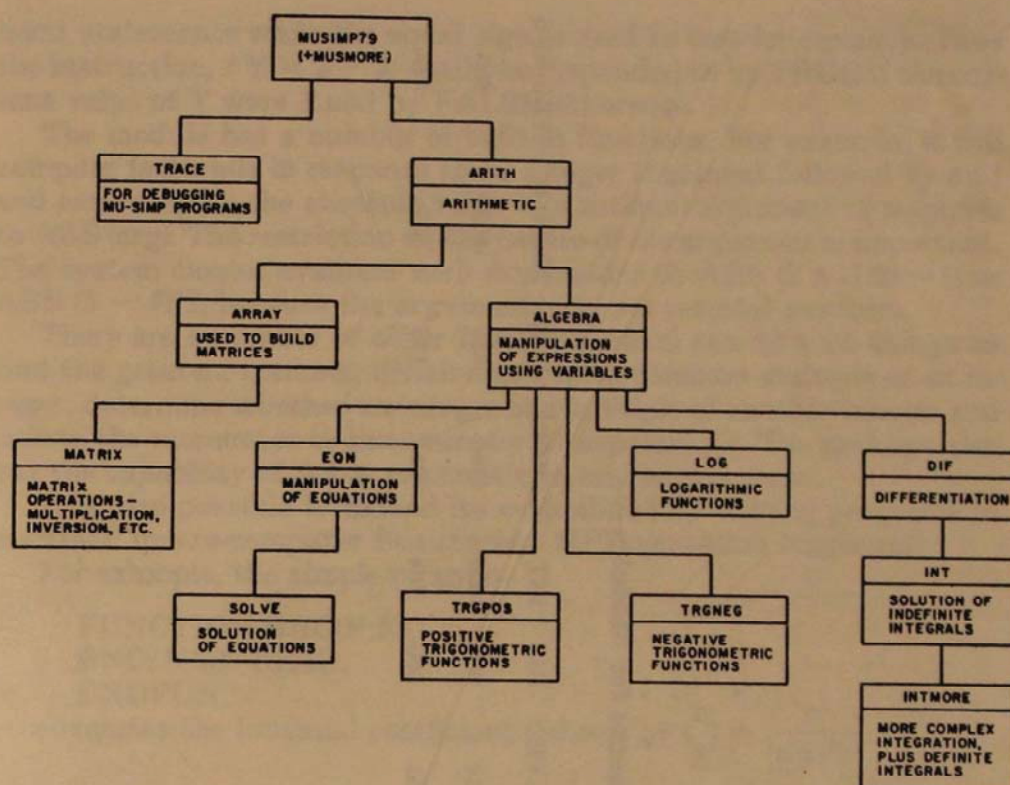
FIGURE 1. Functional dependency chart for the packages in muMATH-79. To run any package shown here, muSIMP-79 and all the packages connecting it to that desired package must be compiled to make a custom muMATH-79 system.

Module capabilities

The ARITH module is necessary for the operation of all the other modules. It provides the basic operations of addition, +, subtraction, −, multiplication, *, division, /, and exponentiation, Λ, as in FORTRAN or BASIC. Also the precedence rules and use of parentheses are similar, but the arithmetic has some disconcerting features. It uses exact rational arithmetic rather than integer or floating point arithmetic. *It does not accept decimal numbers.* It is necessary to enter .01 as 1/100 and 25.16 as 2516/100. Similarly, it will give its answers as rational numbers and will not approximate fractional powers. For example, if asked for the square root of 125 it will write the answer as 5 * 5 Λ (1/2). It also recognizes the symbols #E, #PI AND #I for the base of natural logarithm, π, and $\sqrt{-1}$ and can handle complex arithmetic but it treats these quantities as symbols not as numbers.

As the system handles numbers with up to 611 digits, overflow or underflow will seldom be a problem. However, converting the answer to a readily understandable form may involve laborious digit counting.

When an arithmetic expression is entered into the system, besides typing out the answer the system stores it in the variable #ANS which is available for the next command only. The system also permits assignment statements of the form var: expression;. The : is used for assign-

Table 1. Node Space Requirements for Modules

Module	ARITH	ARRAY	MATRIX	ALGEBRA	EQN	SOLVE	DIF	INT	INTMORE	LOG	TRG-POS	TRG-NEG
Normal	3115	756	892	1946	208	734	580	1420	1760	345	602	680
Condensed	1536	375	497	1160	86	452	360	794	914	186	327	372

Note: A node is four bytes.

ment statements while the equal sign is used to test for equality. Thus the instruction, ? Y = 3 − 2; would be responded to by TRUE if the current value of Y were 1 and by FALSE otherwise.

The module has a number of built-in functions. For example, it will compute factorials in response to an integer argument followed by an ! and can compute the absolute value of a rational argument in response to ABS (arg). The restriction on the nature of the argument is important. The system cannot evaluate such expressions as ABS (2 Λ (1/2) −1) or ABS (3 − #PI) because the arguments are not rational numbers.

There are a number of other functions which can do such things as find the greatest common division and least common multiple of an integer, determine whether an integer is a multiple of another integer and isolate the numerator or denominator of expressions. The package also has the capability of doing arithmetic in any integer base.

It is also possible to extend its capabilities by writing programs in muSIMP (micro-computer Structured IMPlementation language).

For example, the simple program

```
FUNCTION BNC(N,K),
BNC: N!/(N-K)!/K!,
ENDFUN;
```

computes the binomial coefficient defined by $\binom{n}{k} = \dfrac{n!}{(n-k)!k!}$.

muSIMP is a very flexible language which permits both Von Neumann style programming stressing loops and assignment statement and the "applicative" style which emphasizes expressions, functional composition and recursion.

Array and Matrix Modules

The modules give the user the capability to generate arrays (vectors and matrices) and to perform the usual matrix operation. The user generates a column vector by using {   }. The statement Cl: {1,2,3,4}; generates a column (vector) having the four elements 1, 2, 3, and 4. The statement Rl: [11, 3/2, 2 + 2]; generates a three element row matrix with the elements 11, 3/2 and 4. It is possible to use arrays as elements of an array. Thus the command A: [C1, C2]; B: {R1, R1}; generates the rectangular arrays

$$\begin{vmatrix} 1,1 \\ 2,2 \\ 3,3 \\ 4,4 \end{vmatrix} \quad \text{and} \quad \begin{vmatrix} 11 & 3/2 & 4 \\ 11 & 3/2 & 4 \end{vmatrix}$$

On the other hand elements are extracted from an array by a form of index; the array name followed by the indices in square brackets as C1 [I]; R1 [I]; or A [I] [J];.

The matrix package permits algebraic operations on matrices of considerable complexity as muMATH does not share the limitation of BASIC of only one matrix operation in a statement. It permits a statement such as M1: M1 + M2; M1: (M3 + M1 Λ 2) Λ −1; with matrix multiplication being represented by a . rather than an *.

It also has a procedure for solving a set of linear equations of the form SOL: COEFF/RSIDE; which is more efficient than inverting the matrix. The module does not contain a procedure for evaluating a determinant, but a simple program for doing that can be added.

The Algebra, Equation and Solve Modules

The algebra module is basic to the unique capabilities of muMATH as a symbol manipulation system. It permits it to apply the capabilities of the ARITH module to expressions as well as numbers and to determine that $(A+B) \wedge 2 = A \wedge 2 + 2*A*B + B \wedge 2$ just as $(2 + 3) \wedge 2 = 25$.

The module permits you to assign an expression involving variables to a variable by a statement such as Y: $A + B \wedge N + \#PI * A \wedge \frac{1}{2}$; and then use Y in another expression. The module also has a built in expression for replacing any variable in an expression by another expression. This is worked by NEWEX: EVSUB (OLDEX, VAR, REX);.

An important feature of the module is its ability to rearrange an expression in different forms. How it expresses or rearranges a function is determined by a series of control variables. Table 2 taken from an

Table 2. The effect of control variables on symbolic manipulation within muMATH-79. The values given to these control variables determine how muMATH-79 manipulates algebraic expressions. Other control variables not listed in this table are TRGSQ, TRGEXPD, LOGBAS, PBRCH, and LOGEXPD, which control trigonometric and logarithmic expressions

Control Variable	Result with Positive Value	Result with Negative Value
NUMNUM	$A(B+C) \rightarrow AB+AC$	$AB+AC \rightarrow A(B+C)$
DENDEN	$\frac{1}{A}(\frac{1}{B+C}) \rightarrow \frac{1}{AB+AC}$	$\frac{1}{AB+AC} \rightarrow \frac{1}{A}(\frac{1}{B+C})$
DENNUM	$\frac{B+C}{A} \rightarrow \frac{B}{A}+\frac{C}{A}$	$\frac{B}{A}+\frac{C}{A} \rightarrow \frac{B+C}{A}$
NUMDEN	$\frac{A}{B+C} \rightarrow \frac{1}{\frac{B}{A}+\frac{C}{A}}$	$\frac{1}{\frac{B}{A}+\frac{C}{A}} \rightarrow \frac{A}{B+C}$
BASEXP	$A^{B+C} \rightarrow A^B A^C$	$A^B A^C \rightarrow A^{B+C}$
EXPBAS	$(AB)^C \rightarrow A^C B^C$	$A^C B^C \rightarrow (AB)^C$
PWREXPD	$(A+B)^2 \rightarrow A^2+2AB+B^2$	$(A+B)^{-2} \rightarrow \frac{1}{(A^2+2AB+B^2)}$
	$(A+B)^3 \rightarrow A^3+3A^2B+B^3$	$(A+B)^{-3} \rightarrow \frac{1}{A^3+3A^2B+3AB^2+B^3}$
	(etc.)	(etc.)

evaluation of muMATH [‖] lists the more important ones and indicates their role. Unfortunately there is no really good set of instructions on how to use them so it is necessary to learn by trial and error.

It is important to realize that the operations on numbers, described previously, can be applied without any modification to expressions. Therefore, with an environment which includes the ALGEBRA and MATRIX modules it is possible to invert an array the element of which are expressions or solve a set of linear equations where some or all the coefficients are expressions rather than numbers. This will have a major influence on applied mathematics and we will discuss some potential applications later.

The EQN module provides the capability of writing equations of the form EXP1==EXP2 and performing operations on both sides. The SOLVE module provides the capability of solving an equation by the instruction ? X: SOLVE (EQUATION, VARIABLE);.

For example, the response to SOLVE (X Λ2 == 4, X) will be $\left\{ \begin{array}{c} 2 \\ -2 \end{array} \right\}$.

As a convenience the == can be omitted from the equation when one side is 0. When there are several solutions they are printed out in a vector whether or not the ARRAY module is part of the environment. However, if ARRAY is part of the environment one of the solutions can be extracted from the vector by a statement such as XPART: x [2];. It should be noted that SOLVE is not a very powerful equation solver; it can solve a quadratic but not a cubic. If it cannot solve an equation, it will print the equation or the factors into which it can resolve it as the solution vector.

Table 3 shows a program for solving a cubic equation which will produce all three roots. In the normal case of an equation with real coefficients the first root will be the real root, but it may be written as the difference between complex conjugate complex numbers. It should be noted that the coefficients need not be real numbers they can be expressions or complex numbers.

The DIF, INT and INTMORE Modules

These modules give the system the capability of performing the basic operations of differential and integral calculus. The DIF module provides for differentiating a function with respect to any of its variables by a statement such as DFDX : DIF (F,X); Differentiation can be nested as in D2FDX2:DIF (DIF(F,X),X); or DDFDYDX:DIF (DIF(F,Y),X);.

The module has the rules for differentiating implicit functions, sums, and products of functions and the derivatives of some basic functions such as powers, cosine, sine, etc. The user can add additional definitions of derivatives of other functions such as Bessel functions to suit particular requirements.

The INT module does simple integrations and take instructions such as INT(XΛ2,X); or INT(1/(A+B+X),X); INTMOR can do more indefinite integrals than INT and also does definite integrals by substituting the limits into the definite integrals. The required form is

DEFINT (FUN, VAR, LL, UL); and it can be nested to do multiple integrals.

Table 3

```
? FUNCTION CUBIC (B,C,D,G,H,R,T,AL),
  T:1/3,AL:1/2,H:(3*C-B^2)/9,
  G:(2*B^3-9*B*C+27*D)/27,R:(G^2+4*H^3)^AL,R:(-G+R)^T
      +(-G-R)^T)/2^T-B/3,
  G:B+R,H:C+G*R,T:(G^2-4*H)^AL,
  CUBIC:{R,(-G+T)/2,(-G-T)/2},
  ENDFUN;
```

Applications of Symbolic Manipulation

Our work with muMATH is still in its early stages but we will discuss two investigations using its capabilities: implementation of the Post inversion formula for Laplace transforms and the use of symbol manipulation to facilitate the numerical solution of nonlinear equations.

Inversion of Laplace Transforms

The Post inversion formula [10] is

$$f(t) = \lim_{k \to \infty} \frac{(-1)^k}{k!} \left(\frac{k}{t}\right)^{k+1} \frac{dF^k}{dp^k}\bigg|_{p=k/t}. \tag{1}$$

It is seldom used because of the difficulty of evaluating the derivative in any but the simplest cases. Table 4 is a program for computing the sequence of approximations.

Applying it to $(1 + p)^{-1}$ gave

$$e^{-t} = \lim_{k \to \infty} \left(1 + \frac{t}{k}\right)^{-(k+1)} \tag{2}$$

which is a valid result but not as good as $(1 + t/k)^{-k}$.*

The transform e^{-p}/p correspond to a step function, the original being 0 for $t < 1$ and 1 for $t > 1$. The sequence obtained by the program can be interpreted as

$$e^{-k/t} * \sum_{j=0}^{k} \frac{1}{j!} \left(\frac{k}{t}\right)^j. \tag{3}$$

*Its inferiority can be seen by considering the linear term which is $-k+1/k$ rather than -1.

This has the correct limiting behavior but the transition is not sharp for any for which the results can be calculated without getting overflows on the computer.

Table 4. Program for Inverting Laplace Transforms

```
FUNCTION LAPIN(LAP,P,N,T,SEQ,C,K),
SEQ: 1/T*EVSUB(LAB,P,1/T),K:1,C:−1,
LφφP
LAP:DIF(LAP,P),SEQ: SEQ,C*(K/T) (K+1)*EVSUB(LAP,P,K/T),
WHEN K=N,SEQ EXIT,
K:K+1,C:−C/K,
ENDLOOP
ENDFUN;
```

Notes: (1) It is not necessary to include C and K in the function call. (2) The expression LAP will be altered by execution of the function.

Continuation Methods

These methods transform the problem of solving a set of nonlinear equations to the integration of an initial value problem. The simpled form reduces the solution of

$$f (\vec{X}) 0 \qquad (4)$$

to the integration of

$$J \frac{d\vec{X}}{dt} = - f (\vec{X}_0) \qquad (5)$$

subject to

$$\vec{X} = \vec{X}_0 \text{ at } t = 0 \qquad (5b)$$

where J is the Jacobian $\frac{\partial f_i}{\partial x_j}$. The solution of the differential equation at $t = 1$ is the solution of (4).

The difficulty is that (5) is an implicit system making it necessary to solve a set of linear equations each time the derivative are needed. By using the symbolic manipulation system the system can be transformed into an explicit system thus eliminating the need to solve the sets of linear equations.

We have applied this to a system of three equations describing the equilibrium of CO_2, CO and O_2 used by Na [8] as a test case for the conventional continuation method. We obtained very good results and plan to extend this approach to larger problems.

Conclusion

While application is far from simple, our small symbol manipulation system appears to be a very useful tool for attacking a number of problems in engineering analysis.

It is our belief that such system will become widely used in the near future and will have an important influence on the types of methods that will be found most convenient.

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Social Science Section

Civil Religion Versus Churchly Religion

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Abstract

A longitudinal survey of clergy attitudes toward two stages of the United States Space Program reveals several different relationships between church religion and civil religion. For some clergymen the two religious perspectives are compatible, but for others they are at odds. The cross pressures of political attitudes (nationalistic or internationalistic) and theological orientation (liberal or conservative) are seen to cause inconsistent attitudes toward the space program depending on the level of nationalistic flavor associated with the particular space flight.

Robert Bellah has suggested that civil religion is a phenomenon separate from the religion of the churches and is worthy of analysis in and of itself as a system of beliefs and ceremonies (Bellah 1967). While some writers have denounced the narrow ethnocentrism of civil religion (Marty 1959, Eckardt 1958, and Herberg 1955) others, such as Bellah, and Greeley (1972) insist that civil religion may enable the United States to develop a more enlightened position of social justice regarding domestic and international issues. In other words, while civil religion can legitimate what is petty, it can also stand in judgment of such pettiness and direct people beyond a narrow nationalistic perspective.

Since both civil religion and the religion of the churches have liberal and conservative elements it might be appropriate to ask what relationship exists between the religion of the churches and civil religion. Bellah notes that this relationship has been "singularly smooth" (1967, p. 13), although there has been a tendency for civil religion to have "a pervasive and dominating influence within the sphere of church religion (ibid., p. 12).

The questions that guide the research reported here are, "What is the relationship between traditional churchly religion and civil religion?" and, "How do clergymen function in the civil religious enterprise?" It is herein suggested that the United States Space Program should be seen as an event of civil religious importance.

Not only was the small step of Neil Armstrong on the moon's surface a "giant leap for mankind," as he called it, but it marked an historic event of nationalistic importance for the American society. Beginning in 1961 President John F. Kennedy had announced that the manned lunar landing of American astronauts was to be a national priority. Throughout the ensuing years reports of Soviet excursions into outer space were given with a commentary on where the Russians were relative to the Americans in their "race to the moon."[1]

Because of the tremendous expense (estimated at 20 billion dollars) and degree of scientific expertise involved in the Apollo program, it had symbolic value as indicative of America's energies and commitment to reach out to new horizons. Although Americans were somewhat divided in their opinion of the space program it served for many of them as a unifying force, an event in the nation's civil religious experience. The planting of the American flag on the moon seemed to many observers to suggest the claiming of new territory despite an official disclaimer to the contrary, or at least the charting of new frontiers. (Apollo 11 could thus be seen to parallel the westward expansion of the American frontier society.) Unlike the times of crisis related by Bellah (1967), the American Revolutionary War and the Civil War, the space program represented a battle against nature itself, as well as a form of competition with the Soviet Union.

The present study analyzes the reaction of Christian clergymen to the manned lunar space program (Apollo series). Taking a cue from Bellah's statement that civil religion has been able to "mobilize deep levels of personal motivation for the attainment of national goals" (ibid., p. 13) it is suggested here that the Apollo program was a significant element of the American civil religion, and that an analysis of clergy attitudes toward the program provides insight into the relationship between civil religion and church religion.

[1] In 1961 the Soviets successfully sent the first astronaut into earth orbit; in 1963 they sent up the first woman astronaut; in 1964 they launched the first three-man crew; and a Russian cosmonaut was the first man to "walk in space" in 1965. These events are documented in Sobel (1965).

Attitudes Toward the Space Program

The manned lunar space program provided a series of events which affords an opportunity to determine religious responses to a national civic issue. A longitudinal mailed survey of clergy opinion of the program was conducted in 1969 and 1971 on the occasions of America's first and third lunar landings Apollo 11 and 14 (hereafter referred to as Survey I and Survey II). Respondents were 190 Catholic and Protestant clergymen from a midwest metropolitan area of approximately one million inhabitants.[2]

It was found that a majority of the church leaders favored the space program as indicated by a positive or supportive response to questions on inception. "Should man have started the space program?"; continuation, "Should man continue and try to explore the planets?"; and the normative position of the church, "What position should your church take toward the program?" In this study these three dependent variables together are called the "space attitude." A small minority of the respondents (from 8-18% depending on the question) reacted negatively to the Apollo 11 program and a somewhat larger minority (13 to 31%) opposed the Apollo 14 mission. The minority which opposed the program's inception and continuation tended to be clergymen who fit into the ideal-type sect pattern. A disproportionate number of the opposition was less educated, older, more conservative in theology, and was affiliated with sectarian churches. (Seventy-nine percent of those who opposed inception were members of sect churches, and eighty-seven percent of the opposition came from those of a conservative theological persuasion.) However, none of these demographic or religious indicators seemed to be related in any systematic way to the question of what the normative position of their church should be.[3]

The uniqueness of the clergy answer to the normative position of the church is further demonstrated by looking at the association between the three dependent "space attitude" variables. There was a strong association between responses to the questions on inception and continuation of the space program with a contingency coefficient of .6460 (Cmax = .8165). (Eighty-seven percent of those favoring the program's inception also supported its continuation, while ninety-three percent of those opposed to the program's inception also opposed its continuation.)

In contrast to this strong association, the clergymen's view of the appropriate normative position of the church was not highly correlated with the other dependent variables of inception and continuation. (Contingency coefficients for these relationships were .2455 and .2806 respectively.) Of special note is the fact that sixty-seven percent of those who felt that the church's position should be one of "woeful concern"[4] about

[2]This survey was described in an earlier unpublished article.

[3]This question was framed to elicit a response in terms of the local church which the clergyman was serving. It may be possible that some of the respondents answered in terms of national or regional denominational positions.

[4]The answer categories for the normative position of the church were three-fold—"prayerful support, disinterest, and woeful concern." Admittedly the last category is somewhat ambiguous, for "concern" could be interpreted as a measure of support or interest. We believe the qualifying adjective "woeful" elicited a response roughly equivalent to "opposition."

the space program had a positive evaluation of the program's inception, and twenty-nine percent of those who opposed inception suggested church support! Likewise forty-seven percent of those who said that the church should be "woefully concerned" favored continuation, and thirty-eight percent of those who opposed continuation urged church support. In other words, from one-half to two-thirds of those who felt the church should not support the program did support its inception and continuation nevertheless. About a third who expressed opposition to inception or continuation felt that their church should support it. It would appear that many of the clergymen's personal, theological assessments of the space program were in conflict with their ecclesiastical positions.

In order to better understand the motives behind the positions taken by the clergymen let us look at several correlates of their space attitudes.

Attitude Correlates

The space program could be variously interpreted as a scientific-technological breakthrough, an event in man's quest for knowledge, and as a major national feat. In order to determine the relationship between the space attitude and each of these interpretations, questions were asked about the alleged conflict between science and religion, the norms by which children should be socialized, and about the nationalistic aspects of the space program.

Sociologists, among others, have been interested in documenting the existence and analyzing the outcomes of the conflict between science and religion (Stark 1963; Greeley 1965; Vaughan, Smith and Sjoberg 1966; and Merton 1957). Since the landing of men on the moon was a scientific and technological feat of great magnitude, it was felt that clergymen's views about the relationship between science and religion would have an important association with their space attitude.

In both surveys about thirty-three percent of the clergymen felt that there was conflict between science and religion. Another seven percent were uncertain, and sixty percent said there was no conflict. It had been hypothesized that the feeling that science and religion conflict with each other would be related to a negative view of the space program.

Table 1 suggests that this relationship did indeed exist. Those who felt there was no conflict between science and religion were more apt to support the space program's inception and continuation than those who felt that such conflict did exist. This attitude constellation is not, however, related in any statistically significant fashion to the question on the normative position of the church. When asked how serious the conflict between science and religion was, those who said it was very serious also showed greater opposition to the space program. Apparently the space program was seen by some respondents as a scientific enterprise, and their opposition to it was related to concern that science was in some way antagonistic to religion.

Another attitude constellation examined was the norms by which socialization of the young should be governed. When the respondents were asked what was the most important thing for a child to learn to prepare

Table 1. Attitude Toward Science and Religion and the Space Attitude, in percentages (Survey I)

Space Attitude	Conflict of Science with Religion?		
	Yes	Undecided	No
Evaluation of Inception[a]			
Positive	69	50	88
Undecided	12	42	10
Negative	19	8	2
	(N=58)	(N=12)	(N=106)
Desirability of Continuation[b]			
Positive	62	25	79
Undecided	12	58	10
Negative	26	16	11
	(N=58)	(N=12)	(N=105)

[a] $X^2=24.9319$, df 4, $p < .001$, C=.3522, Cmax=.8165.
[b] $X^2=28.8157$, df 4, $p < .001$, C=.4233, Cmax=.8165.

him for life they ranked the norms as follows: "to think for himself," 54%; "to help others when they need help," 24%; "to obey," 20%; "to work hard," 1%; and "to be well liked or popular," 1%. Because the space program was a result of man's innovative quest for knowledge it was anticipated that clergymen who valued the norm of independent thinking would be more supportive of the space program and those stressing obedience would be less supportive.

As predicted, the norm of independent thinking was more closely related to support of the space program's inception and continuation than was that of the norm of obedience. An unanticipated association was that the helping orientation was also related to support for the program. Some respondents did equate the space program with man's progressive "social betterment." Table 2 illustrates these associations. Here again the normative position of the church was unrelated to the independent variable.

The relationship between nationalism or patriotism and religion has been explored by Berger (1967), Warner (1953), and others. In order to investigate the nationalistic overtones of the space attitude respondents were asked if it was important for America to beat the Russians to the moon. Fifty-four percent answered affirmatively, twelve percent were undecided, and thirty-four percent answered negatively. The ministers were also asked if the planting of the American flag on the moon was important to them. Sixty-one percent said "yes," eight percent were undecided, and thirty-one percent said "no."

Table 3 indicates the association between the space attitude and the

Table 2. Socialization Norms and the Space Attitude in Percentages, (Survey I)

Space Attitude	Most Important Socialization Norm[a]		
	To Think	To Help	To Obey
Evaluation of Inception[b]			
Positive	84	91	50
Undecided	12	9	25
Negative	4	—	25
	(N=95)	(N=42)	(N=36)
Desirability of Continuation[c]			
Positive	73	81	47
Undecided	14	9.5	20
Negative	13	9.5	33
	(N=94)	(N=42)	(N=36)

[a]Due to a low frequency count other choices are not included.
[b]$X^2=28.2092$, df 4, p < .001, C=.3744, Cmax=.8165.
[c]$X^2=13.2455$, df 4, p < .02, C=.2674, Cmax=.8165.

combined scores on the two above-mentioned questions regarding nationalism.[5] Little relationship was found between levels of nationalism and views of the program's inception or continuation. Those who scored high on the nationalism index would however have their church be more supportive than low scorers. What is most significant about this table is that out of the thirty-one different attitudinal and structural variables used in this study, Nationalism emerged as the variable with the strongest association with the normative position of the church. This finding may help interpret the difference between the other dependent variables and the normative position of the church.

Belief in the presence of conflict between religion and science, and clergy values relating to socialization of the young were associated with churchmen's views toward the space program's inception and continuation but not their suggestion for the church's normative position. On the other hand their nationalistic stance was more closely related to the normative position of the church than to the issues of inception or continuation. While the majority of the clergymen had a consistent space attitude (having similar views on each of the three dependent variables), it appears that many church leaders were able to hold one set of attitudes toward the space program as it related to their educational philosophy

[5]A positive response to both questions was scored as "high," and other combinations were scored "low." The coefficient of internal consistency for this Nationalism Index was .5646, and the reliability coefficient was .72.

Table 3. Nationalism and the Space Attitude, in Percentages (Survey I)

Space Attitude	Nationalism Index Scores	
	High	Low
Evaluation of Inception[a]		
Positive	73	79
Undecided	23	9
Negative	3	12
	(N=91)	(N=98)
Desirability of Continuation[b]		
Positive	68	66
Undecided	20	10
Negative	12	24
	(N=91)	(N=97)
Normative Position of Church[c]		
Positive	80	52
Undecided	13	23
Negative	7	25
	(N=90)	(N=97)

[a] $X^2 = 10.6498$, df 2, p < .01, C=.2309, Cmax=.7071.
[b] $X^2 = 6.3678$, df 2, p < .05, C=.1809, Cmax=.7071.
[c] $X^2 = 17.0885$, df 2, p < .001, C=.2893, Cmax=.7071.

and theological orientation, and another set of attitudes toward the program as it related to national achievements. What is of special interest is the compartmentalization of attitudes which enabled some clergymen to support civil religion as it related to the space program even though the program ran counter to their philosophical and theological expressions of religiosity.

Cross-Pressures Illustrated

There is indication that some clergymen were laboring under cross-pressures with regard to the formation of a consistent set of attitudes toward the space program. Their experience of cross-pressures varied with their religious identity. In this study the clergymen's religious identity was measured both subjectively and objectively. Respondents were asked to classify themselves as "liberal, moderately liberal, middle of the road, moderately conservative, or conservative." They were also asked if their theological views had undergone changes in the preceding ten years. Objective measures of religiosity included questions which

determined the orthodoxy of their view of God, and a specification of their denominational affiliation.

Table 4 which correlates clergy self-classification in the first survey with their attitudes toward the space program, gives tentative verification of the cross-pressure thesis. Churchmen who called themselves

Table 4. Theological Self-Categorization and the Space Attitude, in Percentages

Space Attitude	Theological Self-Categorization of Respondent	
	Liberal	Conservative
Evaluation of Inception[a]		
Positive	91	67
Undecided	6	19
Negative	3	14
	(N=66)	(N=72)
Desirability of Continuation[b]		
Positive	79	55
Undecided	12	18
Negative	9	27
	(N=66)	(N=71)
Normative Position of Church[c]		
Support	65	70
Disinterest	14	19
Concern	21	11
	(N=66)	(N=70)

[a]$x^2 = 34.28$, df 2, $p < .001$, C=.4461, Cmax=.7071.
[b]$x^2 = 9.64$, df 2, $p < .01$, C=.2564, Cmax=.7071.
[c]$x^2 = 2.64$, df 2, $p < .30$, C=.1377, Cmax .7071.

"liberals" (numbering thirty-eight percent of the sample) and "middle of the road" (twenty percent of the sample but whose scores are not indicated here) were more supportive of the program's inception and continuation than the "conservatives" (forty-two percent of the sample). The conservatives opposed inception and continuation more than the liberals but reversed their attitude on the question of the normative position of the church. On that question the conservatives gave greater support and less opposition than the others. Thus a portion of the conservative group apparently shifted from opposition to support of the program between the questions of continuation and church position.[6] This shift,

[6]It is necessary to emphasize the tentative nature of this evidence since the level of statistical significance on the question of the church's position does not meet acceptable standards.

we believe, is due to the conflict the conservatives experienced between their theological understandings of man's "incursion" into outer space and their feelings of responsibility as leaders of churches to give support to this nationalistic endeavor. Thus, for some ministers church religion (theology) and civil religion were at odds with one another.

Not only did some of the conservatives show a cross-pressure at work in their attitudes but some liberal clergymen likewise were caught in cross-pressures. While liberals were most supportive of inception and continuation their response to the church's position was one of much less support and greater opposition. Whereas the theological and personal response of the majority of the liberals was to support scientific endeavors such as the space program, their response to the position of the church was not as supportive. Some of them actually suggested that religion should not be used to support a nationalistic endeavor.

Similar evidence is forthcoming when the space attitudes are correlated with the response to the question on whether or not the clergymen's theology has changed, to a question on theological skepticism and to the denominational affiliations of the churchmen when classified according to Glock and Stark's fourfold typology (1965). Although the number of respondents from any particular denomination is too small to draw statistically significant conclusions, the general pattern which emerges deserves comment. Among respondents from the United Church of Christ, one of the theologically most liberal denominations in the sample, two-thirds supported inception and continuation, but 44% gave the negative response with regard to the normative position of the church. At the other extreme, conservative Baptists (excluding American Baptists) gave less than 60% support to either inception or continuation of the program, but 84% of them indicated that the church should react positively.

Attitude Change Over Time

The results of the second survey, conducted two years later, at the time of the Apollo 14 flight, suggested that clergy opinion had changed considerably. In 1971 only 52% of the churchmen favored continuation of the space program. Twenty percent fewer clergymen felt their church should be supportive of the program than in 1969.[7]

Almost half of the respondents felt their churches should be neutral and not support or oppose the program. This response was probably due to the uncertain status of the space program in 1971. The budget of the National Aeronautics and Space Administration had been cut, several other lunar missions had been cancelled and there was much less interest in competition with the Russians. In fact, the Soviets publicly stated on October 24, 1969, that they had indefinitely postponed any attempt to

[7]The response categories for the normative position of the church in Survey II were support, neutrality, and opposition. The wording was changed to evoke a less ambiguous response, but we feel that the basic connotation remained the same.

fly men to the moon.[8] In light of these uncertainties one would anticipate that churchmen would not be able to decide whether to support or oppose the program.

The relationship between the variables of the normative position of the church and continuation of the program was more consistent in the second survey. The major inconsistencies were cases where those who supported or opposed continuation expressed the feeling that their churches should be neutral with regard to the program.[9] There is some indication that consistency of attitudes toward the space program varied with the theological background of the respondent. In 1971 liberals gave strong support for the continuation of the space program, but a third urged that the church take a neutral position. A majority of the conservatives opposed continuation and an even greater majority urged church neutrality. Similar findings emerged whether clergymen's self-categorization, a measure of theological orthodoxy, or specific denominational affiliation was used.

These relationships between religious identity and the space attitude suggest that in 1971 some clergymen were still facing cross-pressures between their personal and theological evaluations of the space program and the position they thought their church should take. The net outcome of these cross-pressures was that some liberals and conservatives were in similar position of institutional uncertainty.

Attitude Correlates in Survey II

In the first survey we noted that churchmen with strong nationalistic feelings tended to suggest that their church should support the space program. Two questions in the second survey were geared to measure the relationship between the space attitude and nationalism. The first was, "Our country should disarm regardless of whether or not other countries do the same." Agreement with this statement would suggest a feeling that the nation's security is not best achieved through the force of arms. Eighteen percent of the churchmen (here called "pacifists") agreed with this statement, while 15% were undecided. The remaining 67% which opposed unilateral disarmament represents a more traditional form of nationalism. Table 5 shows the association between this measure of nationalism and the church position (the association with the question on continuation was not statistically significant). The pacifists were evenly divided on the normative position of the church. The more traditional "militarists" were divided between urging church support and neutrality.

A second question measured internationalism, or support for a transnational form of government. Table 6 is based on the association of the space attitude with the question, "If a workable plan could be developed for a single world government I would like to see the United States

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[8]In Robert W. Peterson, editor, Space: *From Gemini to the Moon and Beyond* (N.Y.: Facts on File, Inc.), p. 210.

[9]The question of inception of the space program was not asked in the second survey.

**Table 5. Attitude Toward Disarmament and the Normative
Position of the Church, in percentages (Survey II)**

Space Attitude	Respondents View of National Defense		
	Militarist	*Undecided*	*Pacifist*
Normative Position of Church[a]			
Positive	49	39	35
Neutral	41	61	30
Negative	10	—	35
	(N=83)	(N=18)	(N=23)

aX^2=13.8751, df 4, p < .01, C=.3172, Cmax=.8165.

**Table 6. Attitude Toward Internationalism and the
Space Attitude, in Percentages (Survey II)**

Space Attitude	Respondents View of World Government		
	Nationalist	*Undecided*	*Internationalist*
Normative Position of Church[a]			
Positive	28	50	53
Neutral	59	47	30
Negative	13	3	17
	(N=32)	(N=26)	(N=70)
Desirability of Continuation[b]			
Positive	38	59	56
Undecided	12	22	17
Negative	50	19	27
	(N=33)	(N=27)	(N=70)

aX^2=10.4757, df 4, p < .05, C=.2751, Cmax=.8165.
bX^2= 7.3386, df 4, p < .10, C=.2312, Cmax=.8165.

join." Fifty-five percent of the clergymen agreed with this statement, while 25% rejected it. In this table 59% of the nationalists, who would reject world government, are uncertain as to the proper church response to the space program. The internationalists are much more supportive. This marks a reversal of the findings from the first survey. In 1971 nationalistic clergymen were less supportive of the space program than the

internationalists. It may well be that this reversal occurred precisely because the space program had lost much of its nationalistic flavor.

With regard to the question on continuation a similar difference emerges although the association is not statistically significant. A majority of the internationalistic church leaders favored continuation (which now lacked nationalistic overtones) but 50% of the nationalists opposed it, perhaps because of the diminution of its nationalistic spirit.

Interpretation and Discussion

The occasion of man's first trip to the moon was an important historical event of civil religious significance. The first man to walk on the moon, astronaut Neil Armstrong, spoke of his feat as the beginning of a new stage in the evolution of man. In their book, *First on the Moon*, Armstrong et al., said,

> Five hundred million years ago, the moon summoned life out of its first home, the sea, and let it onto the empty land. For as it drew the tides across the barren continents of primeval earth, their daily rhythm exposed to sun and air the creatures of the shadows. Most perished—but some adapted to the new and hostile environment. The conquest of the land had begun.

> We shall never know when this happened, on the shores of what vanished sea. There were no eyes or camera present to record so obscure, so inconspicuous an event. Now, the moon calls again—and this time life responds with a roar that shakes earth and sky.

> When a Saturn V soars spaceward on nearly four thousand tons of thrust, it signifies more than a triumph of technology. It opens the next chapter of evolution. (p. 421).

The Apollo program symbolized America's ability to do the "impossible." As the nation was able to place astronauts on the moon and bring them back safely, in like manner it was thought, she could deal with urban and racial problems, and make the world safe through her military presence in Indochina and elsewhere. In retrospect America has not been able to solve these problems. Such difficulties have, if anything, become compounded in the subsequent decade. Since the Apollo successes the United States has begun to be more mindful of the ultimate necessity to work not autonomously, but in international concert in space, energy research, etc.

As Bellah has indicated, civil religion has both a narrow, nationalistic theme and a broader internationalistic thrust, or at least the potential for such a thrust. The church leaders whose attitudes were reported in this study represent both wings of this civil religion. Some were very nationalistic, while others were more internationalistic in their orientation.

It is difficult to distinguish the religion of the churches (theology and philosophy) from civil religion, for in our secularized world there is inter-action between the realms formerly distinguished as "sacred" and "secular." Thomas and Flippen (1972) questioned the distribution of civil religion in American society. It is indeed illusive. It is especially difficult to sort out the manifestations of church religion from those of civil religion when the same functionaries are involved in both realms.

It is apparent that for some clergymen the space program deserved comment and response as a civil religious event, distinct and separate from "church religion" (or theology). For others, perhaps a majority, no distinction was made between civil and church religion, as the various indicators of the space attitude were answered consistently.

Not only are presidents and statesmen spokesmen for civil religion, but some clergymen are involved in its defense as well. But their role is not necessarily that of leader in the civil religion. Indeed the clergy function may be more like that of laymen, or lower level functionaries in the civil religious enterprise. Perhaps clergymen could not be leaders in the civil religion precisely because their loyalties were divided between the national and denominational religions they espoused. The role of the clergy in the civil religious enterprise deserves further investigation.

Our data shows how conventional religious attitudes and civil religious attitudes can change in response to various social changes. Having demonstrated that the two forms of religion interact what is needed is a model that clearly defines civil religion as distinct from other forms of religion.

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Arenas of Crime in Rural America

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Because the public is becoming more aware of the rapid increase in official crime rates in rural America, it is important that serious study should be given to rural crime. In the past most criminological research has focused on urban crime, and most theories of crime explain why crime rates are higher in the cities than in rural areas. By default, rural crime has been neglected in the attempt to understand crime.

This error has now come to light, and there is an emerging literature which focuses on rural crime. However, because of the dominance of urban theories, many kinds of rural crime are being overlooked in recent studies. This paper suggests a variety of arenas which must be studied in rural areas. The arenas are defined by economic, geographical, and social forces which contribute to radically differing kinds of crime. The arenas, and the kinds of crime which need study, include the following: 1) Ku Klux Klan crimes in the rural south; 2) crimes committed in coal mining areas of Appalachia; 3) crimes on the American farm; 4) crimes committed on reservations of the American Indian; 5) crimes of Eskimo villages; 6) cattle rustling in the West; 7) violations against the United States Department of Agriculture; and 8) frauds used to buy or sell land.

While the category "urban" has a homogeneous character, this paper illustrates the difficulty involved in using "rural" as a sociological category. "Rural" is a category of heterogeneity.

Literature on rural crime is not common. This scholar has never seen a discussion of rural crime in an American textbook on crime. To my

knowledge there has been only one book published on the topic of rural crime, a book published in 1933 (Smith, 1933). A survey of all major journals related to criminology, sociology, rural sociology, juvenile delinquency, and criminal justice reveals that since 1920 only about seventy essays appear in the literature which deal in any way with rural crime. Over a period of sixty years, that comes to only slightly more than one such article per year. Because the literature is scarce, most of those articles are "written blind," without knowledge of other essays written on the topic. Footnotes and references in those articles reveal a basic lack of knowledge as to what other authors have written on the subject (Warner, 1979, 1980c).

In 1980 I presented a paper before the West Virginia Academy of Science which briefly reviews the literature on rural crime published since 1920, with reference to articles published in Europe prior to that date (Warner, 1980b). I noted at that time the need to pursue arenas of rural crime which have been largely neglected by students of criminology, and in this paper I want to make more clear what those arenas are. I present this paper as a work-order, an outline of topics which need scholarly development. I suggest eight crime arenas in rural America, arenas which have largely, or totally, been neglected by students of criminology.

1. The *Ku Klux Klan* had its origin in Pulaski, Tennessee, in 1865, immediately after the Civil War. The organization was formed by six defeated Confederate soldiers who invented a word based on the Greek word *kuklos*, or "circle." Using some ancient Scottish symbols and paraphernalia they frightened newly-freed slaves as they rode horseback in the middle of the night donning strange costumes and carrying torches. The feat became great fun, and quickly spread throughout the South. The Ku Klux Klan was officially incorporated in Nashville, Tennessee, in April, 1867, electing retired Confederate General Nathan Forrest as its Grand Wizard. Using terrorism, violence, even murder and mutilation, the Klan was effective in driving out many Yankee carpetbaggers who held office under Reconstruction. For this heroic effort the Klan became greatly popular in the Confederate states, but because of the increased use of violence, General Forrest officially disbanded the organization just two years after its incorporation.

That did not end Klan activities, and in the next fifty years it has been estimated that some 5,000 black persons were lynched by Klantype activities. The Klan was reorganized in Atlanta in 1915 under the leadership of William Simmons, and has terrorized blacks and civil-rights leaders ever since that time. The Ku Klux Klan was involved in race riots, lynchings, killings, castration, terrorism and intimidation in the years following the Supreme Court decision to desegregate schools, and has recently been involved in killings in Greensboro, North Carolina. Many Klansmen have been indicted for violations of the 1964 Civil Rights Act. They were involved in the killings of three civil-rights leaders in Mississippi in 1964, the bombing of churches and freedom schools in the deep South, the killing of four black children in Alabama attending a Baptist Sunday School, the killing of Mrs. Viola Luizzo in a civil-

rights related incident in Alabama, and in 1980 they reportedly drove a Methodist minister from his parish in West Virginia. Most textbooks on crime do not list the Klan in the index, nor do they spend even one sentence on the topic. That is because criminology has been a study of urban crime (Warner, 1980a; Lowe, 1967; Tannenbaum, 1924; Mecklin, 1924; and *Southern Exposure*, 1980).

2. To my knowledge no American textbook on crime has ever discussed the crimes related to coal mining. Those crimes include fraud in the purchasing of coal mine rights, political favoritism in defending the mines and controlling legislatures in Appalachia, violations of health and safety laws which have caused the early death or incapacitation of countless miners, intimidation of labor organizers, violations of laws written to protect the land from destructive surface mining, etc. These crimes are neglected by criminologists who study fist fighting and burglarly in the cities (Caudill, 1963, 1971; Hume, 1971; Ambrister, 1975; Gaventa, 1980).

The history of West Virginia is rich with the stories of violence, labor organization conflicts, mine disasters which could have been prevented if laws had been observed. This is a significant arena for the study of rural crime.

3. In the past decade there have been several studies of crimes committed on the American farm. Most important of those studies is the work of G. Howard Phillips at Ohio State, a rural sociologist in the Department of Agriculture. Phillips studied the perceptions of rural crime as seen by members of the Ohio Farm Bureau; he studied records of sheriffs in nine rural Ohio counties; he studied self-reports of delinquency as reported by teenage boys in nine rural counties; and a team of researchers guided by Phillips went to farm homes asking for victim reports. Phillips found that farmers were not much worried about crime, and that their greatest complaint was vandalism, particularly vandalism related to the destruction or damaging of rural mail boxes. The farmers' second greatest complaint was the theft of gasoline from farm tanks (Phillips, 1975, 1976 a,b,c, 1979).

In a study of rural delinquency in East Tennessee, Bolton and Brown studied official reports and inquired of key persons as to the problems and needs of juveniles and juvenile delinquency in sixteen counties, including the urban Knox County, eight other counties with sizeable towns, and six very rural counties. Most of the delinquency in those counties was relatively minor and property-related. There was little fear of violent crimes by juveniles (Bolton and Brown, 1978).

Unfortunately, those studies focus on the categories of crime developed by criminologists in urban areas, and they make no mention of the larger white-collar and political-type crimes which are perhaps more dangerous to farmers and rural workers.

More insidious, we believe, are agriculture-specific crimes. The most noted agriculture-specific crime in recent American history is the Billie Sol Estes scandal in Pecos, Texas, a fraud against the United States Department of Agriculture, many local farmers in Pecos, local banks and

businessmen, a fraud which cost its victims more than $30 million[1] (CQA, 1962; U.S. 1965).

More recently some two hundred farmers in southwestern Iowa were robbed of much or all of their life savings in the Prairie Grain Company embezzlement in Stockport, Iowa. Here a wheeling-dealing grain elevator operator, Raymond Keller, killed himself on January 31, 1980, just hours after the state auditor showed up at the elevator to begin investigations. Nowhere in the literature will one find such stories, although authorities in Iowa claim that in the past five years there have been 35 grain elevator failures, all due to mismanagement, fraud, embezzlement, and fast dealing with people who trust a man reputed to be a community leader (Braun, 1980; Ingrassia, 1980).

In Ohio, at the same time Dr. Phillips was studying rural crime, the Dola Farmers Exchange elevator was found to have failed some 300 Ohio farmers in or near Hardin County, Ohio. The crimes related to that failure, making newspaper headlines in September, 1975, do not appear in Phillips study (Shutt, 1975; Dady, 1975; "Receiver," 1975; "Dola Farmers," 1975).

4. The United States Department of Agriculture is caretaker of programs governed by more than seventy laws which carry with them criminal penalties. The USDA administers laws under Titles 7, 15, 18, 21, and 42 of the United States Code. Those laws include plant quarantine, cotton sampling, warehouse regulations, tobacco controls, wheat marketing regulations, laws related to animal fighting, potato regulations, the protection of horses, meat inspection, school lunch, food stamps, egg inspection, diseased animals, to name only a few.

Prior to the Billie Sol Estes case, there was no coordinated investigating agency within the USDA to deal with law violations, but as a result of that case Secretary of Agriculture Orville Freeman created an Office of Investigator General within the USDA. That office has served as the model for OIGs in other bureaucracies in the United States federal government, and now the new Inspector General Act of 1978 (Doherty, 1979). So many investigations did the USDA make that by 1975 that agency could boast of the third largest investigative force in the federal government (Graziano, 1975).

During the six-month reporting period from October 1, 1979, to March 31, 1980, the Inspector General of the USDA issued 447 audit reports and 976 investigation reports, identifying $73 million in recoveries, savings, erroneous payments, management improvements, incorrect loan amounts penalties, claims, fines and judgments, resulting in 307 indictments. During that same period 208 convictions were handed down based on the work of the OIG USDA. Those investigations covered some 300 programs administered under USDA (USDA, 1980).

Seventy-three million dollars, 208 convictions, 307 indictments in one six-month period, achieved by the third largest investigating force in the

[1]The story can be traced through any of the popular news magazines such as *Time, Newsweek,* or *U.S. News and World Report,* beginning immediately after the F.B.I. arrested Estes on March 29, 1962.

federal government. Yet one will search long and hard to find one single sentence in American criminology textbooks dealing with the USDA. In America "crime" is urban.

5. Cattle rustling is a major problem for American farmers and ranchers. In Alabama, for instance, 676 head of cattle were reported stolen in the last three months of 1978, and authorities believe the actual figures are much higher. Cattle theft today little resembles the rustling seen in Western movies. Today the rustler may not know how to ride a horse, but he can fire a gun and drive a truck. Rustlers can butcher a cow in a matter of minutes and sell it the next day in a market three states removed from the crime (Rickey, 1979; "Midnight," 1974; "Todays Rustler," 1979). But except for stories in popular magazines, the criminological literature on this rural crime is scant indeed.

6. The American Indians, most of whom live on rural reservations in Arizona, New Mexico, and South Dakota, and in rural Oklahoma, experience the problems of crime more than any other ethnic group in America. Rates of homicide, suicide, alcohol-related violations and all FBI "index crimes" are well above the national mean. American Indians are more likely to be arrested and to spend some time in jail and in prison than members of any other ethnic group (Stewart, 1964; Ogden, Spector, Hill, 1970).

The American Indian experiences alienation and anomie caused by culture conflict, subjugation, poverty, unemployment, and by the dishonesty of the law givers. No other group in America has been lied to so much as the American Indian, lied to by those who represent our government. It was the law which was broken when President Jackson marched Cherokees and Seminoles to Oklahoma, a march which the Cherokees call the "Trail of Tears." It was the law which was broken by General Custer when he invaded and massacred the Southern Cheyennes at Washita, Oklahoma, a tribe who believed in the law even after Colonel Chivington broke the promise made by President Lincoln when Chivington massacred the Cheyennes at Sand Creek, Colorado, telling his men to kill women and children because "nits make lice"[2] (Brown, 1971). Little wonder that while white Americans were celebrating the Bicentennial in 1976, the American Indian was celebrating the centennial of Custer's Last Stand, when the Indians "got their act together" in June, 1876. There are no such stories in American criminology textbooks.

7. Alaska is our largest and most rural state. The population of the state is smaller than that of the capital city of most American states. There are more square miles than there are human beings in Alaska. In Barrow, Alaska, a police force of seven men police the Northern Slope, an area roughly the size of Montana. Villagers call the police in Barrow on the one telephone in a village; often the lines are down. A single drunk Eskimo may terrorize a town for 48 hours, shooting windows and all moving objects, while no one can reach the telephone or the CB radio. Alaska state laws are often in conflict with village mores and folkways,

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[2]For a good discussion of the alienating effects of imposed law, see Theodore John Rivers (1978).

the state police must take into account both the law and the local customs (Hippler and Conn, 1972, 1973; Angell, 1978, 1979a, b; Moeller, 1979a, b). The story of "bush justice" is fascinating indeed, but it will not be found in American criminology textbooks.[3]

8. Each year nearly a million persons are lured to Florida for free dinners, movies, pep talks, and a chance to "put your money in land." Unfortunately, that "land" has often turned out to be under water, unimproved, or unlike the plot the "sucker" was shown in the pictures. In the early 1970s Americans contracted to spend some $5 billion on second or retirement homes, vacation lots, or land investments. A significant portion of that money was given to "confidence men" with fraudulent claims.

So alluring is the turnover of cash that some of America's largest corporations, including International Telephone and Telegraph (ITT) entered the arena of the "great land hustle." So willing are so many unsuspecting older Americans to turn over their life savings for a retirement in dreamland, often sight unseen, that land fraud has become a paradise for confidence men. In 1971 the White House Conference on Aging listed reform of land sales among the most urgently needed consumer protection measures.

Irregular and illegal practices include selling lots with false promises to pave and provide utilities, selling a lot different than the one seen by the buyer or the picture shown to the buyer, pressuring older Americans into purchasing something they do not need and cannot afford, and a long list of "tricks of the trade." The super-salesman, with his edge on confidence skills and high-pressure tactics, is certain to win in the contest in which the only rule is *caveat emptor* (Paulson, 1972).

Conclusion

The eight arenas of rural crime do not exhaust the list. Not included are such arenas as crimes in oil fields, crimes committed against or by migrant farm workers, violations of fish and game laws (poaching), and certainly a host of other geographical, economic and social segments of society which make crime in the country a very different thing than the phenomenon described by most American criminologists. This paper is presented not as one more illustration of "normal science," but as a call for a totally new paradigm for the study of crime in America.

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Special Publication Section

Can Science Save us?
The Past President's Address

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Brother and Sister Scientists! It is not often that the West Virginia Academy of Science elects as its president a member of the social sciences. The Academy is rooted in the Department of Biology at West Virginia University, and a quick glance at the table of contents of the *Proceedings* of recent years indicates that that Department remains central to the Academy. While there are so many papers read on the topic of biology that that discipline has to be subdivided into sections in order to accommodate them all, the disciplines of sociology, political science, economics and geography have to be combined in order to provide enough papers for a single section.

Similarly, a visit to the Junior Academy Science Fair, held every year at West Virginia Wesleyan College, makes it abundantly clear that in comparison to the natural sciences, the social sciences are embarrassingly weak in secondary schools in the state. Frankly it is almost humiliating to judge the meagre work of the students in the Social Science division of the Junior Academy, and to note the strong contrast to the exhibits in the Natural Science divisions.

Today I want to discuss the role of science in the study of human social behavior, hoping to throw some light onto this obvious weakness of the social sciences in our Academy.

I. In order to establish our rightful niche among the academic disciplines, August Comte (1798-1857) proposed a schema one and one-half centuries ago which only recently has been seriously challenged by

his academic heirs, and today admittedly it is challenged by only a few. Comte's schema he called "the hierarchy and the filiation of the sciences," presented in his monumental work, *The Positive Philosophy* (1853), published first in French between 1830 and 1842 in six volumes.

In this schema Comte argued that there is a brotherhood among the sciences, the blood-bond of which is a common method. Each science has passed through a similar process of maturation, moving from the infancy of the *theological* state—in which explanations are given in terms of a pantheon of capricious deities, to an adolescence, the *metaphysical* stage—in which phenomena of this world are explained in terms of universal order and natural laws, to a final adulthood of the *positive* stage, marked by reliance upon the scientific method.

The pattern of the growth of knowledge is marked not only by the stages through which the various sciences have passed, but by the orderly emergence into maturity first of the simpler sciences and later, with the passage of the centuries, of the more complex sciences. Astronomy, physics and chemistry, the simpler of the sciences (in that order) were the first to press through the stages to maturity, followed by biology and finally sociology, the most complex of the sciences. In the fourth decade of the nineteenth century there was but one discipline yet mired in the adolescence of metaphysics: the study of human interaction. Comte took it upon himself to press this most complex discipline up from the quagmire of armchair philosophy and into the arena of the scientific method. For this Herculean effort he is remembered as the Father of Sociology.

Admittedly, Comte was ambitious! Not only did he aspire for his discipline the perfection of science; in the crystal ball he had the prescience to see forward to the day when sociologists will be kings, when legislators will pay homage to the greatest of the sciences.

Roughly translated, his argument might be rephrased as follows. Sociology is the brother (not the weak sister) of the older sciences, albeit the younger brother. We have been slower to mature because we were the last in the birth-order. Your simpler sciences were born first, and indeed have matured more rapidly than ours. The methods required for the analysis of human interaction must be more sophisticated than those of the mundane study of biology and chemistry because our subject is more wiley than the paramecia and the neutrons which you locate under your electronic microscopes. More wiley, indeed, because human beings are infinitely more complex than the lower forms of inorganic or organic matter. But scientists of the world, beware: the youngest brother of all will someday grow to be the Atlas under whose shadow you will labor as proletarian servants. The imagery is intoxicating!

II. Standing, as we do, at a distance of one and one-half centuries past those dreams of this father of our sociology discipline, let us check to see where those dreams have led us, and how well the goals of those dreams have been realized. First, the dream that this science should one day rule our planet.

The dream has not died. Lester F. Ward, the first president of the American Sociological Society (1906-1907), presented Comte's work order to America's early sociologists. American society, Ward argued,

should not drift aimlessly to and fro, backwards and forwards, without guidance. Rather, the group should carefully study its situations, comprehend the aims it desires to accomplish, study scientifically the best methods for attainment of these, and then concentrate social energy to the task set before it (Dealy, 1927: 82).

The folly of democratic legislatures was only too obvious to Ward, and these were well on their way to senescence, retained, perhaps, as museum pieces,

> but more and more they will become a merely formal way of putting the final sanction of society on decisions that have been worked out in the . . . sociological laboratories (Ward, 1906: 8).

Edward A. Ross, Ward's nephew by marriage, affirmed this role to be played by sociology. Sociology, he wrote, does not

> meekly sidle in among the established sciences dealing with the various aspects of life; it aspires to nothing less than suzerainty (Ross, 1926: 8).

That early ambition of the discipline gave way, in the 1930s and 1940s, to a new mood which eschewed social criticism and reform, a mood of scientism which David Riesman later caricatured when he wrote of the pedants of the discipline who,

> with no philosophic training, consume their time affixing exact degrees of significance to insignificant correlations and never get around to discovering anything new about society (Riesman, 1953: 48).

After the Second World War the labors of social science, however, began to bear fruit in the United States. These fruits are apparent in decisions of the Supreme Court, actions of the Executive and Legislative branches of the Federal Government.

In 1954 the Supreme Court handed down the famous desegregation decision ordering the schools in America to open their doors to persons of all races, arguing that the "separate but equal" policy established in an earlier Court decision (Plessy v. Fergusson, 1896) must be overturned. Significant in that decision was the brief filed by the NAACP (National Association for the Advancement of Colored People). An appendix to the NAACP brief contained statements by thirty-two social scientists describing the harm done to non-white children under the policies of segregation (Linda Brown, et al. v. Board of Education of Topeka, 1954). The desegregation order was a victory for social science, for it was perhaps the most visible sign to date of the Government "putting the final sanction of society on decisions that have been worked out in the . . . sociological laboratories" (Ward, 1906: 8).

A second indicator of the fruits of social science may be seen in the plans of John F. Kennedy's New Frontier legislation. The work of Robert

K. Merton, Albert K. Cohen, Richard A. Cloward and Lloyd E. Ohlin led to a theory of juvenile delinquency which stressed "blocked opportunities." Daniel Patrick Moynihan (1969: 51) summarized the theory and demonstrated its influence on the Kennedy administration.

> Cloward and Ohlin argued that delinquents were resorting to desperately deviant and dangerous measures in order to *conform* to the routine goals of the larger society. If that society wished them to conform not only in their objectives but in their means for achieving them, it had only to provide the *opportunity* to do so. Opportunity was the master concept. And what else was America all about?

Kennedy took seriously the professors of his own alma mater (Harvard University). Under his leadership, and later that of Lyndon B. Johnson, the administration developed numerous programs which were to provide opportunities for underprivileged youth. Among those programs were Mobilization for Youth, the War on Poverty, Head Start, the Job Corps, Vista, Neighborhood Legal Services, and the Community Action Program. On May 31, 1962, Kennedy launched the Mobilization for Youth program in the White House garden. The problem of juvenile delinquency, Kennedy said, is "really a question of young people and their opportunity" (Moynihan, 1969: 59).

Another approach to juvenile delinquency is represented in the work of Frank Tannenbaum (1938), Edwin M. Lemert (1951, 1967), Howard S. Becker (1963), Kai T. Erikson (1964), John I. Kitsuse (1964), and Edwin M. Schur (1971, 1973), known collectively as the "labeling theorists." In sum, these social scientists argue that the juvenile justice system has been overzealous in tracking down deviant youngsters, that once a youngster is caught in the web of that system he is "labeled" delinquent, is treated thus and learns to act as such, and that for many juveniles the best thing that could happen is that they should be left alone, kept out of the juvenile justice system. That theory made an impact on the thinking of Senator Birch Bayh, major author of the Juvenile Justice and Delinquency Prevention Act of 1974. The major import of the Act was a program of funding provided to the several states on the condition that they make significant progress in removing children from jails, divert youngsters from the judicial system whenever possible, and provide alternatives to incarceration. The significance of this Act can be seen in recent legislation in the State of West Virginia (West Virginia Code: 1977, 1978, 1979) in recent rulings by the State Supreme Court (1977, 1978, 1980) and most importantly in the significant reduction in juvenile incarcerations in the State (W.V. State Advisory Group, 1980).

The work of social scientists has made its mark on governmental decisions and actions since the Second World War, and to that extent the dream of Comte, Ward, Ross and others has been partially fulfilled.

Yet it must be said that while Congress and the Courts have turned to social science for instructions in the problems of race and delinquency, the results have been somewhat less than glorious. The Kerner Commission (National Advisory Commission on Civil Disorders, 1968) found

that our nation is moving toward the polarization of two separate societies, one white and one black. School desegregation has been only moderately successful, and there are some indications that that process is now in reverse. Progress along the lines of juvenile delinquency is discouraging indeed, such that more than one scholar has agreed with Robert Martinson (1974: 25) that, in terms of rehabilitation programs, "nothing works."

III. If the first line of assessment has been a *political* one, the second is *scientific*. In comparison with the older brothers—those who have placed men on the moon and photographed the craters on Saturn, who have terminated polio and unlocked the atom, measured the size and the age of the universe, how shall we assess the scientific successes of sociology? The report is modest indeed!

True enough, we have won no Nobel prizes; there has been no Einstein among us. Frankly, we have not yet heard from our Newton, our Kepler, our Pasteur, our Lister or our Linaeus, our Spinoza or even our Euclid. As you in the natural sciences are only too ready to point out, not only have we been unable to *solve* human social problems, we have made jolly little progress in *understanding* poverty, war, crime, exploitation, economic depression, racism, terrorism or human despair. Not only are we poor in our explanations; we are unable to make reliable predictions. Take note of this. Nearly three millenia ago the great Hebrew prophet Amos predicted the invasion of Israel twenty-three years in advance; yet our CIA, using computers, spy planes, satellite surveillance and sophisticated information techniques could only report the recent Soviet invasion of Afghanistan as a *fait accompli*!

Although our accomplishments are meagre, we have our defenders. Robert Merton, a past president of the American Sociological Association, criticizes the exercise in which I have just engaged as "misplaced masochism," and argues that the comparison between the accomplishments of physics and sociology is unfair because we are still a fledgling discipline. In 1949 Merton wrote, "Between twentieth-century physics and twentieth-century sociology stand billions of man-hours of sustained, disciplined, and cumulative research" (1949: 6-7). A critic of Merton wrote twenty years later that "a significant dent has been made in the 'billions of man-hours'" without much to show for it (Bernstein, 1976: 18). A more recent defender of Comtean orthodoxy, Ernest Nagel (1961), shows powerfully that while the scientific method has yielded as yet unsatisfying results in the study of man, no one to date has adequately proven that the method cannot work. But criticizing Nagel's logic, Bernstein responds:

> But we must be careful not to draw the wrong conclusions
> from Nagel's analysis. There is a slippery path here along
> which many mainstream social scientists have all too easily
> moved. No good reasons have been advanced to demonstrate
> the impossibility of social science, therefore it is possible.
> From this it seems a small step to claim that since it is possi-
> ble, it is likely or probable that a genuine social science will

be achieved—if we work hard enough and are sufficiently ingenious in formulating and testing hypotheses, models, and explanatory theories. Then it appears almost irresistible to believe that one *ought* to adopt a properly scientific attitude to advance the maturity of the social disciplines. One need not cite Hume, who warned about the dangers of moving without friction from talk about what is, or what is possible, to what ought to be done (Bernstein, 1976: 42).

There is something magic which has intoxicated us in the social sciences and which is not unlike the story told to me by a friend. When she was about four years old she remembers swinging, stomach down, on the backyard swing trying to recite perfectly the words to "The Night Before Christmas" because, she believed, if she did this perfectly she would never grow old. When she was eight, she could see that her magic was not working and gave it up.

But the formula dies hard. One does not have to read far in the journals of the social sciences to discover that most of the chores carried out in the disciplines are largely following the work-order set forth by Auguste Comte. The array of numbers, the concrete "social facts," the reliance on statistical methods gives proof of the claim that the myth lives on. The reverse of my friend's magic, we believe that *we will grow old* if we say the words in perfect order and with no mistakes.

IV. Today Sociology is in a state of chaos and reorganization. There is no dominating paradigm and there is no school of thought which appears to be prepared to establish hegemony over the study of human interaction. But if one listens carefully to the noises on the ground, he may discern one theme which is held in common by many of the emerging camps: a distaste for the positivism of Auguste Comte, Talcott Parsons and Robert Merton. That distaste takes many forms: the phenomenology of Alfred Schutz (1967); the *verstehen* of Max Weber (1949); the hermeneutics of Max Horkheimer (1972); the constructionism of Peter Berger and Thomas Luckmann (1967); the symbolic interactionism of Herbert Blumer (1969); the ethnomethodology of Harold Garfinkel (1967); and the critical sociology of Jurgen Habermas (1972), to mention only a few of the leading figures opposing positivism.

While none of the scholars mentioned above would ask to discard the scientific method in the search for truth, all are quick to point out the severe limitations of that method. Central to this critique of positivism are several themes.

1. The epistemological problems discussed by Hume and Kant.

2. The requirement that the study of human interaction include the understanding of meanings (*verstehen*), an understanding not penetrated in the search for cause and effect.

3. The significance of freedom in human interaction.

4. The all-too-uneasy alliance made between positivism and capitalism.

5. The myopia created when the study of epistemology was eclipsed by the philosophy of science.

6. And for Habermas and the Frankfurt School, the absolute political requirement of the search for truth, that such search cannot be meaningful without the parallel search for freedom and justice necessary for the "ideal speech situation."

V. In this paper I have attempted to demonstrate that the application of the scientific method to the study of human behavior has not achieved the glory of which Auguste Comte dreamed, and that while there are those who argue that we must therefore work harder, there is an emerging array of scholars who argue that science alone is wholly inadequate for the study of society.

Twenty years ago George Lundberg raised the question, "Can Science Save Us?" (1961), and then proceeded to answer his own question in the affirmative. Today it is not so certain. The limitations of science were long ago recognized by Tolstoi, who complained that science was unable to answer the only questions important for us, "What shall we do and how shall we live?" (Weber, 1946).

I believed that Tolstoi overstated the case. But he does point to the problem which we who study human interaction must face.

Acknowledgements

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Annual Business Meeting
West Virginia Academy of Science
Room 332 Percival Hall
West Virginia University
Morgantown, West Virginia 26506

April 11, 1981   9:00 a.m.

President Clarkson called the meeting to order.

The minutes of the 1980 Annual Business Meeting were read by Dr. Phillips. Dr. Swiger moved, seconded by Dr. Fezer, to accept the minutes. Motion passed.

Dr. Pauley gave the treasurer's report (a copy is enclosed). Dr. Swiger moved, seconded by Dr. Phillips, to accept the report. Motion passed.

Dr. Clarkson announced that the Index for the first 50 volumes of the Proceedings will be printed.

Dr. Clarkson proceeded with the election of the President-Elect for 1981-82, and the Secretary for 1981-84. Dr. David Blaydes of West Virginia University was elected President-Elect. Dr. John Chisler of Glenville State College was elected Secretary.

Dr. Clarkson announced tentative plans for the 1982 Annual Meeting at Davis and Elkins College, Elkins, WV, on April 2 or 3.

Elizabeth Bartholomew announced the death of Paul Price, past State Geologist, and a member of the West Virginia Academy of Science.

Miss Bartholomew pleads with members of the Academy to inform her of any member who has moved. She needs the new address. Returned mail costs the Academy precious dollars which can be used more wisely.

Dr. Warner gave an interesting talk titled, "Can Science Save Us?"

The meeting was adjourned by Dr. Clarkson.

WEST VIRGINIA ACADEMY OF SCIENCE
ANNUAL TREASURER'S REPORT

1980

April 11, 1981
WVAS Executive Committee
West Virginia University
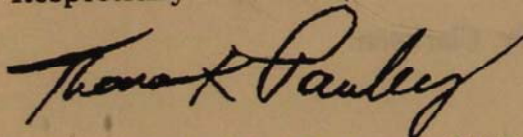Morgantown, West Virginia

January 1, 1980 to December 31, 1980
CASH RECEIPTS

Balance on hand January 1, 1980		$ 9,553.79
Dues	1,462.00	
Institutional memberships	500.00	
Proceedings	1,578.50	
Talent Search	10.00	
Annual Meeting	484.00	
Page charges	277.50	
Interest on Savings	386.03	
TOTAL RECEIPTS FOR YEAR	$ 4,698.03	
TOTAL RECEIPTS AND BALANCE ON HAND	. $14,251.82	

CASH DISBURSEMENTS

Printing (McClain)		$ 4,729.27
Printech		278.95
Contributions		1,080.00
Annual Meeting		365.63
Postage		73.16
Supplies		22.18
Miscellaneous		7.67
TOTAL DISBURSEMENTS		$ 6,556.86
RECEIPTS LESS DISBURSEMENTS		($ 1,858.83)
CASH ON HAND DECEMBER 31, 1980		$ 7,694.96

(Savings $1,932.78)
(Checking $1,762.18)
(Certificate of Deposit $4,000.00)

Respectfully submitted,

Thomas K. Pauley

Thomas K. Pauley, Treasurer, WVAS
   We, the undersigned members of the Audit committee, have examined the records of the treasurer of the WVAS from January 1, 1980 to December 31, 1980, and find them to be correct.
Richard L. Banks
David A. McCoun
K. B. Roswell