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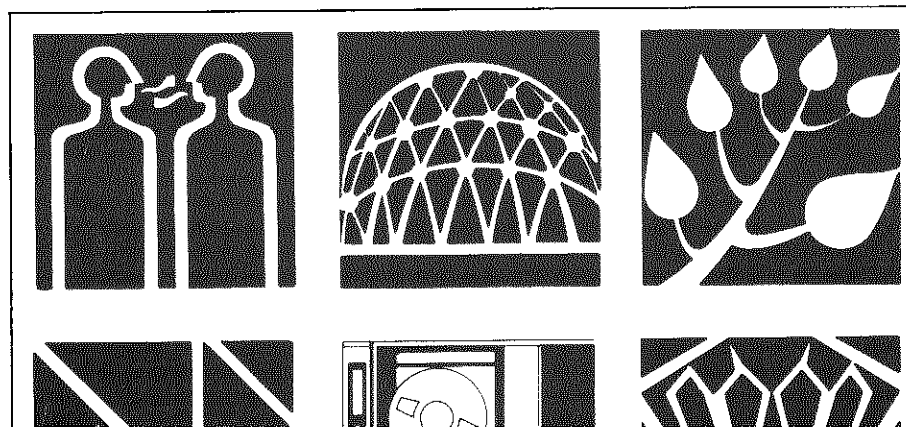
# Proceedings of the West Virginia Academy of Science

# 1988

**Papers o**
**the Sixty-Third Annual Sessio**



# Proceedings of the West Virginia Academy of Science 1988


## Vol. 60—No. 2, 3, and 4
## PAPERS OF
## THE SIXTY-THIRD ANNUAL SESSION

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**Salem, West Virginia**
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# Contents

We greatly appreciate the efforts of Dr. John Chisler and Ms. Debora Starcher in the typesetting of this number.





Published by the West Virginia Academy of Science, Inc. Manuscripts for publication (which normally should have been read at an annual meeting of the Academy) should be sent to the Editor, E. C. Keller, Jr., Department of Biology, West Virginia University, Morgantown, W. Va. 26506-6057. Proof, edited manuscripts, and all correspondence regarding papers for publication should be directed to the Editor.

Applications for membership in the Academy and dues should be sent to Roy B. Clarkson, Treasurer, at the above address. Changes of address should also be sent to Roy B. Clarkson at the above address. Correspondence concerning library exchanges should be directed to the Director of Libraries, West Virginia University, Morgantown, W. Va. 26506.

## 1988 WEST VIRGINIA ACADEMY OF SCIENCE AWARDS

### Science Talent Search Awards

| | |
|---|---|
| First Place: | Michael C. Demchik, plaque and $100; Jefferson High School (Shenodoah Junction) |
| Second Place: | Jeffrey G. Gray, plaque and $50; Linsly School (Wheeling) |
| Third Place: | Rachel S. Brown, plaque and $25;Keyser High School (Keyser) |

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At its 1988 Annual Meeting, The West Virginia Academy of Science recognized "Outstanding West Virginia High School Teachers of Science or Mathematics." These first of annual recognition awards were, and are, sponsored by a special grant from Union Carbide Corporation.

Three teachers were recognized because they have contributed to and are continuing to help high school science aspirants reach their goals. They are:

Ms. Hazel Bowen - Chemistry Teacher, 12 years, Barboursville High School

Ms. Phyllis Barnhart - Chemistry Teacher, St. Marys High School

Mr. Howard Post (retired) - Biology, General Science, Algebra, Chemistry, and Physics, 42 years, Lost Creek High School.



# Papers of the 1988 Meeting

# Botany Section

## Updates on the Vascular Flora of West Virginia. IV.

William Homer Duppstadt
*Department of Biology*
*West Virginia University*
*P. O. Box 6057*
*Morgantown, West Virginia 26506*

**Abstract**

Seventeen species of vascular plants have been recorded during the past year at the West Virginia University Herbarium (WVA) as additions to the flora of West Virginia (based on Strausbaugh and Core, 1978). Unless otherwise noted, the nomenclature and distribution information follows Fernald, 1950.

**The new species are as follows:**

CUPRESSACEAE. *Juniperus communis* L. Rapid Creek, ? County: *Lee C. Corbett s. n.*, August 10, 1892; Randolph County: *G. B. Rossbach s. n.*, July 9, 1950 and Pendleton County: *Rodney Bartgis s.n.*, July 28, 1984. This plant is in our range and is to be expected. Mr. Bartgis says that his collection is from a native stand. Previous collections were thought to be from cultivated or escaped specimens.

POACEAE. *Poa autumnalis* Muhl. ex Ell. Wetzel County: *Edward Estep* 1286, May 11, 1980. This species is in our range and is to be expected.

CYPERACEAE. *Scirpus torreyi* Olney. Hardy County: *Rodney Bartgis s. n.*, August 8, 1987. This plant is in our range and is to be expected.



CYPERACEAE. *Carex woodii* Dewey [*C. tetanica* Schkuhr var. *woodii* (Dewey) Wood]. Ritchie County: *Allison W. Cusick* 24,200, May 8, 1987 and Summers County: *T. F. Wieboldt* 6372, June 6, 1987. *C. woodii* is in our range and is to be expected.

CYPERACEAE. *Carex oligosperma* Michx. Hardy County: *Rodney Bartgis s.n.* June 13, 1985. The range of this plant is to our immediate north, and it is to be expected in West Virginia.

JUNCACEAE. *Juncus trifidus* subsp. *carolinianus* Hamet-Ahti. Pendleton County: *Rodney Bartgis s.n.* and *Craig Stihler*, July 28, 1987. This subspecies of *J. trifidus* is in our range and is to be expected.

ORCHIDACEAE. *Spiranthes ochroleuca* (Rydb.) Rydb. Hardy County: *H. A. Allen* 7450, September 24, 1939 (voucher at US); Pendleton County: *Allison W. Cusick* 24,878, September 27, 1985; Preston County: *E. S.* and *Mrs. Steele s.n.*, September 10, 1898 (voucher at US) and *Charles Beer s.n.*, September 29, 1984. Randolph County: *Allison W. Cusick* 24,881, September 27, 1985. The range of *S. ochroleuca* is to our immediate north and this species could be expected in the mountains of West Virginia (Luer 1975).

BRASSICACEAE. *Erysimum asperum* (Nutt.) DC. Grant County: *Rodney Bartgis s.n.*, June 1, 1987 and Grant County: *E. E. Hutton s.n.* and *Bill Alexander*, June 15, 1987. *E. asperum* is a western species and this find appears to be an eastern disjunct range extension.

ROSACEAE. *Spiraea* X *vanhouttei* (Broit) Zabel. Mercer County: *Rodney Bartgis s.n.*, May 24, 1985. This ornamental is escaping and becoming established (Gleason 1952).

ROSACEAE. *Prunus pumila* L. Monongalia County: *John Sheldon s.n.*, May 11, 1917; Nicholas County: *P.D. Strausbaugh* and *E. L. Core s.n.*, August 16, 1927; Nicholas County: *William Creasy s.n.*, June 19, 1949; Nicholas County: *R. Richardson s.n.*, April, 1974 and Nicholas County: *William N. Grafton s.n.*, April 24, 1986. *P. pumila* is to our north and east and is to be expected in sandy and rocky situation.

FABACEAE. *Lespedeza atuevei* Nutt. Near Hardy-Grant County line: *E. E. Hutton*, June 14, 1985. This species is in our range and is to be expected.

SAPINDACEAE. *Koelreuteria paniculata* Laxm. Jefferson County: *Rodney Bartgis s.n.*, August 14, 1982 and Jefferson County: *Rodney Bartgis*, May 21, 1987. This small tree is native to eastern Asia and is frequently planted in some areas of the eastern U. S. A.

LYTHRACEAE. *Ammannia coccinea* Rottb. Mason County: *Floyd Bartley s.n.*, August 7 and August 17, 1966; *William N. Grafton s.n.*, August 15 and August 16, 1982; *Allison W. Cusick* 26,099, October 17, 1986. *A. coccinea* is a tropical species, but with range extensions north to Ohio, it could be expected in West Virginia.

ASCLEPIADACEAE. *Asclepias longifolia* Michx. Mason County: *E. E. Hutton s.n.*, et al., July 4, 1987. This is a southeastern coastal pineland species.

BORAGINACEAE. *Borago officinalis* L. Mason County: *E. E. Hutton s.n.*, October 18, 1980. This cultivated introduction from Europe is persistant and spreading to waste places.

LAMIACEAE. *Lycopus rubellus* Moench. Ritchie County: *Velma Elliott s.n.*, August, 1969. This species is in our range and is to be expected.

ASTERACEAE. *Petasites japonicus* (Sieb. & Zucc.) Maxim. Mercer County: *E. E. Hutton s.n.*, June 13, 1987. This plant has been introduced from Japan and has become established and is spreading (Ohwi 1965).

## Literature Cited

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Gleason, H. A. 1952. Illustrated Flora of the Northeastern United States and Adjacent Canada.

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Luer, Carlyle A. 1975. The Native Orchids of the United States and Canada Excluding Florida. The New York Botanical Garden, New York, NY.



Ohwi, Jisaburo. 1965. Flora of Japan. Smithsonian Institution, Washington, D. C.

Strausbaugh, P. D. and E. L. Core. 1978. Flora of West Virginia, 2nd edition. Seneca Books. Grantsville, WV.

# A Method for the Isolation of Maize Seedling Nuclei Suitable for Chromatin Analysis[1]

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and

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### Summary

A new method for isolation of nuclei from small quantities of etiolated maize seedlings consists of a brief ether rinse that weakens cell walls and removes cuticles. Vacuum infiltration of gum arabic-octanol solution preceding a shortened incubation period (from 14 to 3.0 h) facilitates turgor pressure equilibration, reduces nuclear fragmentation by homogenization, and prevents cellular autolysis and turnover of chromatin proteins. Smaller volumes of homogenate can be used, and centrifugation through reduced-volume gradients of gum arabic solutions provides a suitable fractionation procedure. Light and electron microscopy reveal that the nuclear fraction is relatively free of cytoplasmic contamination. The nuclei produced are suitable for chromatin isolation and analysis of nucleic acid and protein components.

[1] This investigation was supported by Federal Hatch Proj. 288 and is published with approval of the director of the West Virginia University Agriculture Experiment Station as Scientific Paper No. 1969.

[2] To whom correspondence and reprint requests should be addressed.



### Introduction and Literature Review

The cell wall presents a substantial barrier to normal homogenization techniques. Mechanical methods have been used for plant cellular disruption, however, the shearing forces required to break the rigid cell wall can damage the nucleus and the central vacuole.

Shearing forces can be eliminated in the isolation of nuclei by enzymatically digesting away the cell wall and producing protoplasts which can be lysed to release nuclei. However, care must be taken to remove the enzymes from nuclei by exhaustive washing (16).

Nuclei may also be obtained by incubation in octanol and gum arabic which reduce turgor pressure, stabilize nuclei in plant tissues, reduce shearing forces and yield intact nuclei upon homogenization (22, 35, 36). Octanol also reduces foaming during shearing. Because the long incubation time has been a major disadvantage, the use of a shortened incubation period with an ether rinse of one to three seconds is here investigated. This pre-treatment removes the cuticle, softens the cell walls and reduces the incubation period from 14 h (as in the original protocol) to 3.0 hours. The pretreatment permits more rapid infiltration of the gum arabic solution into tissue. The gum arabic gradients are also a superior fractionation medium for removal of plastids, endoplasmic reticulum, cell walls and other components. The shortened incubation period also prevents autolysis and degradation of chromatin proteins. The addition of protease inhibitors provides additional protection.

Plant cells may have high numbers of chloroplasts which may contaminate the nuclear fraction with chloroplast nucleic acids and proteins. These interfere with spectrophotometric measurements. Chloroplast contamination is eliminated when etiolated seedlings are used as a tissue source since their differentiation ceases at the etioplast stage (30) and these do not sediment during nuclear centrifugation (13). Etiolation also limits the amount of starch formation by amyloplasts.

### Materials and Methods

Maize seeds were supplied by Illinois Seeds, Inc., Champaigne, Ill. Gum arabic, octanol, Tris, Tris-HCl, PMSF, MES, methyl green, and all proteins and nucleic acids were purchased from Sigma Chemical Co. of St. Louis, Mo. Ultra-pure sucrose (density gradient grade, RNase free) was obtained from Schwartz/Mann, Cambridge, Mass. All EM supplies were purchased from Polysciences, Inc., Warrington, Pa., USA.

Spectrum Medical Industries of Los Angelos, Cal., was the source of Spectra/Por dialysis membrane tubing. Protease Substrate Gel Tablets were obtained from Bio-Med Laboratories, Richmond, Cal. All remaining chemicals, reagents, and supplies were purchased from Fisher Scientific Co., Pittsburgh, Pa.

*Preparation of Etiolated Seedlings*

All germination and rinsing procedures were performed at ambient temperature in the dark unless indicated. Seeds of the maize single cross FRMO17 X FRN28 (*Zea mays* L.) were rinsed in water for 1 h, then rinsed and soaked in double-distilled water for 9 h. Following surface-sterilization for 2 h in 0.1% NaOCl (2% Chlorox™ (v/v)), the imbibed seeds were placed in glass trays (34 X 21 cm, 48 seeds/tray) on 0.1% NaOCl-soaked paper and covered with plastic wrap. The seeds were germinated at 30°C for 72 h. The length of the germination period must be uniform, for maize seedlings exhibit considerable phenotypic change over time during their rapid growth phase (6, 26).

*Isolation of Maize Seedling Nuclei*

The isolation procedure was modified from the gum arabic protocol of Tautvydas (36). Operations were performed at 0-4°C. To prevent activity of proteolytic enzymes, 1 mM PMSF and 1 ug/ml soybean trypsin inhibitor were included unless indicated (10, 15, 31). Stock solutions of 0.2 M PMSF were made in isopropanol and due to low solubility in water were added to buffers dropwise with rapid stirring. Since PMSF is a neurotoxin plastic gloves were worn; this also reduced exogenous protease and nuclease contamination. Low salt concentrations and pH below 8.0 also inhibit proteolysis (21).

Buffers A, C, D, and E were made from a 12% (w/v) stock solution of gum arabic, purified by centrifugation at 13,000 g for 1 h and filtration of supernatants through 2 layers of miracloth (31). The pellets consist of insoluble tannins.

Plumules were harvested and separated into 5.5 g sets. One set of tissue was minced into 2 mm segments, then rinsed for 1-3 s with diethyl ether (17). The tissue was quickly placed in 20 ml of Buffer A [4% gum arabic (w/v) in Buffer B: 0.15 M sucrose, 4 mM magnesium acetate, 5 mM 2-mercaptoethanol, 0.1% octanol (v/v), and 5 mM MES, pH 6.0].



Minced tissue in Buffer A was placed under vacuum twice for 4 min each to facilitate infiltration of solution into the tissue. The vacuum was drawn and released slowly to avoid lysis of the central vacuole; appearance of a red-brown color indicates the polymerization of quinones which occurs during plant tissue damage (19). Following infiltration, the preparation was stored at 4°C for 3.0 h in the dark. The shoots should have a translucent appearance.

After incubation, the preparation was sheared at medium speed with a VirTis "45" homogenizer for 8 s. Longer shearing at top speed produced higher yields but severely damaged nuclei. The homogenate was filtered through 4 layers of cheesecloth and 1 layer of miracloth which removes cell wall fragments (21), and was more effective than 157 um polyethylene mesh screening. Retained material was rinsed with 10 ml of Buffer A, and the pooled filtrate was layered over 4 gradients in 45 ml round-bottom centrifuge tubes. Each gradient was constructed by carefully layering three solutions of 9 ml of Buffer B, containing 12%, 10%, and 8% gum arabic, respectively. Gradients were centrifuged at 900 g in a swinging-bucket rotor (HB-4, Sorvall) for 12 min. The majority of cellular debris was retained in the upper layers of the gradient. Supernatants were aspirated with exception of the final 3 ml to avoid disturbing the sediment. Crude nuclear pellets were suspended gently with a rubber policeman and transferred to a teflon-glass tissue grinder (0.13 - 0.18 mm clearance). The bottom of each tube was rinsed with 3 ml of Buffer B. The total pooled volume was slowly homogenized once by hand to remove adhering cytoplasmic material from the nuclei. The suspension was layered over 3 additional gradients for further purification. Following centrifugation at 900 g for 10 min, supernatants were aspirated as before. Nuclear pellets formed as faint rings rather than solid pellets. These were pooled as before and brought to a total volume of 33 ml with Buffer B without trypsin inhibitor. Aliquots were stained, quantified on a hemacytometer, and examined for integrity and contamination. If desired, yields can be increased by performing up to 3 simultaneous, staggered experiments, with separation of treatments on each set of tissue by 10 min to allow preparation time while another set is in the centrifuge. If 3 sets of tissue are used, 6 instead of 4 crude nuclear pellets can be pooled for homogenization and then centrifuged through 4 gradients; this would eliminate 10 min of centrifugation time.

## *Analysis of Maize Tissue and Nuclei by Electron and Light Microscopy*

To assess cellular damage from ether treatment and the 3 h incubation in Buffer B, fresh and treated plumules were examined by electron microscopy. Briefly, minced plumules were rinsed in cold Buffer C, containing 50 mM cacodylic acid and 0.2 M sucrose, pH 7.3 (2, 39). Tissue was fixed in 2.5% gluteraldehyde (v/v) in Buffer C for 1 h, then rinsed in Buffer C. During fixation, preparations were gradually warmed to ambient temperature. Further fixation was provided by 1.5 h in buffered 2% $OsO_4$, followed by buffer rinse. Samples were dehydrated, embedded in Epon-Araldite B, and mounted by standard EM protocols. Sections were post-stained in standard uranyl acetate and lead citrate stains.

Isolated nuclei were prepared for EM by suspension in cold Buffer C and sedimented at 750 g (SS-34 rotor, Sorvall) for 10 min. This and all subsequent supernatants were discarded. Fixation was achieved by suspension in cold buffered 2.5% glutaraldehyde for 50 min, with gradual warming. Nuclear pellets were rinsed via suspension and centrifugation in Buffer C, then suspended in 2% buffered $OsO_4$ for 10 min. Fixed nuclei were centrifuged, then rinsed as above. Final pellets were mixed with a minimal amount of warm buffered 2% agar and spread on a glass slide. When cooled, 2 mm cubes were cut and dehydrated in an ethanol series, with uranyl acetate staining in the 70% step. The agar cubes were embedded, sectioned and mounted as before. For light microscopy, nuclear aliquots were stained by addition of commercial 2% aceto-orcein solution or 0.5% methyl green in 0.6% NaCl (w/v) to a final proportion of 25% of the total volume.

## *Isolation of Chromatin from Maize Seedling Nuclei*

The protocol used was a modification of an intermediate ionic strength method (15). EDTA was added to reduce nuclease activity. Most RNases and DNases have a pH optimum below 8.0, so a lower pH was avoided (9, 38). However activities of plant proteases are found at pH 8.0, and some degrade chromatin proteins when elevated temperatures exist for long periods (20). To avoid degradation, 1 mM PMSF was included in buffers unless otherwise stated, and operations were performed as rapidly as possible at 0-4$^{o}$C. EDTA, avoidance of mechanical fragmentation, and minimal exposure to aerial oxidation can reduce ionic interactions and aggregation in isolated chromatin (18). Shearing has been shown to alter chromatin substructure (11, 27), and all types of mechanical agitation such as sonication, homogenization, and vortexing, must be kept to a minimum (15). Under intermediate ionic strength conditions, chromatin attaches readily to glass, so care is necessary during transfer and suspension. Inclusion of Triton X-100 reduces nuclear membrane contamination (15). The use of the following protocol should yield chromatin suitable for general studies of components, transcription *in vitro*, and separation of template-active regions, with a decreased likelihood of extrachromatin protein contamination.

Isolated nuclei were taken immediately into the chromatin isolation procedure. All supernatants were aspirated and discarded. Nuclei in Buffer A were centrifuged at 1500 g for 10 min (SS-34 rotor). Pellets were removed from the underlying starch with a spatula; this was repeated for chromatin pellets in the next 3 steps as well thereby eliminating the starch. Nuclei were suspended in 40 ml of 75 mM NaCl, 24 mM $Na_2$-EDTA, pH 8.0, then homogenized in a teflon-glass grinder (.004-.006 inch clearance) by one stroke with the motor drive at the lowest setting. Extensive homogenization was avoided to prevent fragmentation of chromatin. The material was centrifuged as before. Pellets were resuspended by homogenization in 4 ml of Buffer D, [10 mM Tris, 2 mM EDTA, and 0.1% Triton X-100 (v/v), pH 8.0]. The suspension was then centrifuged at 4500 g for 10 min. Time of exposure to NaCl or detergent was minimized to avoid solubilization of chromatin proteins. Pellets were again washed in Buffer D via homogenization and centrifugation at 12,000 g for 10 min. A final washing as recommended by Garrard and Hancock (15) was found to be unnecessary for plant chromatin. Pellets were suspended in 10 ml of Buffer D without Triton X-100 and homogenized by one stroke of a tissue grinder (0.18 mm), then slowly stirred on ice for 1 h. Five ml of the chromatin suspension was layered over 32 ml of 1.7 M sucrose, 10 mM Tris, 2 mM EDTA, and 0.5 mM PMSF, pH 8.0. The upper 2/3 of each tube was slowly mixed with a spatula and the gradients centrifuged at 70,000 g for 3 h (AH 627 swinging-bucket rotor, Sorvall). The gelatinous pellets were suspended with a spatula in 10 ml of Buffer E containing 25 mM sodium acetate, pH 6.6, placed in dialysis tubing (6-8000 MW cutoff), and dialyzed overnight against 2 liters of Buffer E with 0.1 mM PMSF, pH 6.6. The dialysate was sedimented for 15 min at 27,000 g. Pellets were suspended in 4 ml of Buffer E with 0.1 mM PMSF by one stroke of a glass-teflon homogenizer (.004-.006 inch clearance).

### *Analysis of Chromatin Components*

Chromatin purity was assessed by UV absorption (3). An aliquot was diluted 1:9 with Buffer E without PMSF and sheared for 3 min at 30 V with a VirTis "45" homogenizer. Sheared material was stirred on ice for 10 min, then centrifuged at 10,000 g (SS-34 rotor) for 30 min. The supernatant was scanned from 230-330 nm on a Gilford model 240 spectrophotometer. Scattering correction for chromatin turbidity was calculated by extrapolation of interference from the higher wavelengths (14). Chromatin treated in this manner is severely damaged, and should not be used for further analysis.

Aliquots of the chromatin suspension were tested for proteolytic activity with a commercial protease substrate assay system. Trypsin activity in 50 mM tris-HCl and 50 mM $CaCl_2$, pH 7.5, was used as a standard, and sensitivity was tested from 0.5 to 35 ug/ml.

Nucleic acids and proteins present in chromatin were quantified by standard assays. Due to the lower solubility of maize chromatin, DNA samples were pretreated in 0.5 N $HClO_4$ for 15 min at $70^{\circ}C$, and concentration was measured by the diphenylamine reaction (4, 5), with facilitation of color development by heating tubes for 15 min in boiling water (12). Calf thymus DNA was used as a standard. RNA was separated from DNA by alkaline hydrolysis in 0.3 N KOH since DNA interferes with the RNA assay (25). RNA concentrations were determined by the orcinol assay (34), with standard concentrations prepared from torula yeast RNA. Proteins were quantified by comparison to bovine serum albumin standards using the Folin phenol method (24).

## Results and Discussion

Maize seedling nuclei of improved quantity and quality for subsequent chromatin isolation and analysis were produced. Yields averaged $1.77 \pm 0.145 \times 10^8$ (SE) nuclei for 19 experiments using 3 X 5.5 g of shoots. Yields were approximately 7 times those obtained previously. A typical nuclear suspension under the light microscope reveals nuclei with various sizes and shapes due to the presence of a variety of cell types within the shoot (Fig. 1). The nuclei stained uniformly with aceto-orcein or methyl green. Cytoplasmic contamination consisted only of a few colorless starch granules.

A major concern with gum arabic procedures is the effect of a long incubation period on cellular structure and gene expression. To shorten the incubation period, the tissue was pre-treated with ether, which has a potential for damaging cells. The effects of the modified treatment upon cellular integrity was assessed by EM. Figure 2 shows the appearance of immature leaf cells from a fresh, untreated shoot. The central cell has a typical morphology, including amyloplasts, portions of the central vacuole, and the nucleus with nucleolus and various forms of chromatin. This is compared to the appearance of tissue treated with ether and gum arabic (Fig. 3). Micrograph A shows an immature leaf cell from the shoot. This cell has a normal appearance, as compared to Figure 2 and to the work of others (23, 33). Cellular membranes are intact and the tonoplast, seen to the right of the nucleus, has not been disturbed. The structure of the nucleus is also similar to that of the cell in Figure 2.

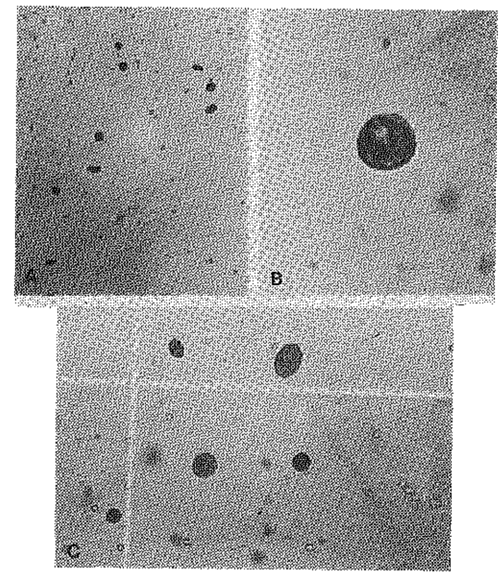


Figure 1. Light micrographs of isolated maize seedling nuclei. Aceto-orcein staining. Magnifications: A, X 544; B, X 3400; C, X 1360.

The most external portion of the shoot is the coleoptile surrounding the immature leaves. These cells are quite fragile and peripheral cells in this tissue showed an abnormal structure, (Fig. 3B). The cell membrane was discontinuous and contracted, and cytoplasmic membranes and organelles were disrupted, including the vacuole. Nuclear chromatin was more contracted, and the nuclear membrane was removed in some areas. The damage is presumably due to the ether exposure, which can extract lipids from cellular membranes. However, the extraction involved little tissue, and was limited only to the peripheral cells. It appears that ether treatment expedites the entry of gum arabic and octanol solutions into the vascular system during vacuum infiltration, and produces the same effect as a longer incubation period. Ether treatment must be used with caution; the damage seen here was incurred after only 1-3 s of exposure. Other authors recommend 30 s or 1 min of treatment (17, 35); this could cause extensive degradation. Isolated nuclei were also observed with EM. Figure 4A shows a typical nucleus containing a nucleolus. Above is part of a nucleus containing chromatin in a less condensed state. Another nucleus is shown in Figure 4B, which shows the nuclear membrane separating from the organelle. This probably occurred late in the EM protocol, otherwise the membrane would have been removed via centrifugation. This micrograph also shows contaminating endoplasmic reticulum on the lower right; however, this contamination was rare. Figure 5 shows additional nuclei which exhibit some degree of fragmentation probably due to the viscosity of the agar. Also illustrated is the general lack of cytoplasmic contamination in the preparation. In all studies, structures resembling plastids or other organelles were not found.

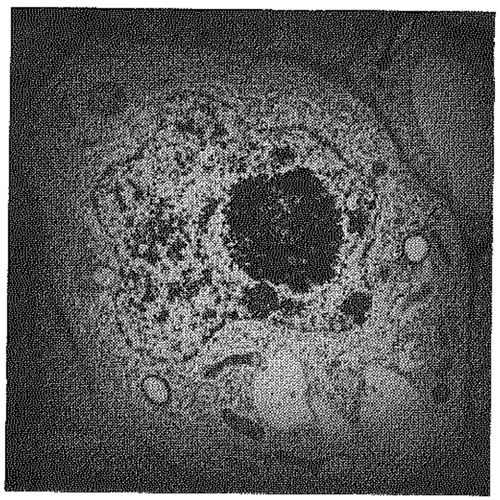

Figure 2. Electron micrograph of immature leaf cell of fresh untreated maize seedling tissue. Magnification: X 10,400.



The purified chromatin fraction isolated from these nuclei was analysed by UV absorption of sheared aliquot (Figure 6). The wavelength scan, showing a typical spectrum with a maximum of 260 nm and absorption at 300-320 nm, which is less than 0.1 of that at 260 nm, is in agreement with the results of others (3, 37). The scan indicates low turbidity, and a lack of chromatin aggregates and nonchromosomal protein.

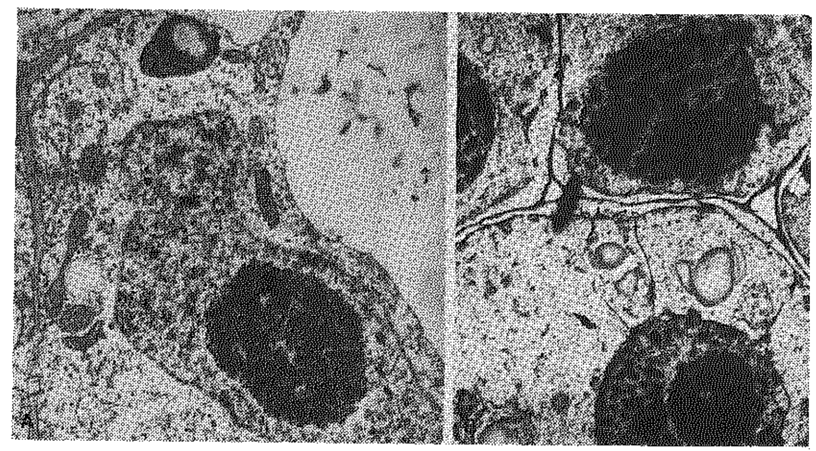

Figure 3. Electron micrographs of cells from shoots treated with ether and gum arabic. A. Undamaged immature leaf cell, magnification: X 13,900. B. Damaged coleoptile cell, magnification: X 12,000.

The final chromatin preparation contained no detectable endogenous protease activity. The assay system displayed considerable protease sensitivity with trypsin standards even at 0.5 ug/ml. Therefore, the chromatin preparation was relatively free of protease activity.

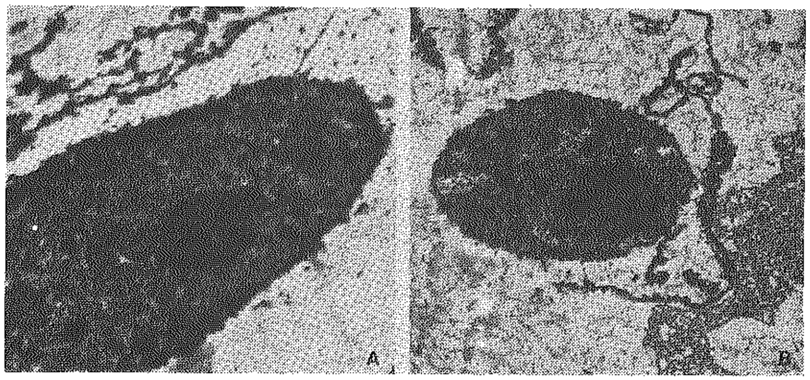

Figure 4. Electron micrographs of isolated maize seedling nuclei. Magnifications: A, X 21,400; B, X 13,900.

DNA, RNA, and protein contents of the isolated chromatin were determined and compared to values obtained in other systems. Protein and RNA contents were 465 ± 31.4 ug (SE) and 171 ± 24.4 ug respectively per 100 ± 7.9 ug DNA. The DNA:protein:RNA ratio was 1.00 : 4.65 : 1.71 based on 6 determinations. The values for protein and RNA were higher than those frequently found in plant and animal chromatin (18, 36, 37). Several studies reported similar DNA:protein values in plant nuclei (17, 32). A similar overall ratio was found in maize seedling nuclei isolated by a different method (35). Higher proportions of RNA and protein were observed in soybean hypocotyl nuclei (8). Therefore, DNA, RNA, and protein values were due to species-specific variation or to developmental or differentiation states. Nuclear values may be different from those of chromatin but differences in isolation methods can also be a significant source of experimental variation. Nucleoli and nucleolar chromatin have higher levels of RNA and protein relative to the remaining chromatin (1, 7), but many methods of chromatin isolation remove these. The protocol used in this report was designed to remove non-chromatin material such as ribonucleoprotein complexes and residual nuclear membrane fragments. Nucleolar chromatin may be present in the final chromatin fraction, and probably contributes to the higher levels of RNA and



protein. The nucleic acid and protein ratios observed were found to be acceptable, since they were similar to values obtained by others for maize seedling nuclei, and fall within reported chromatin ranges.

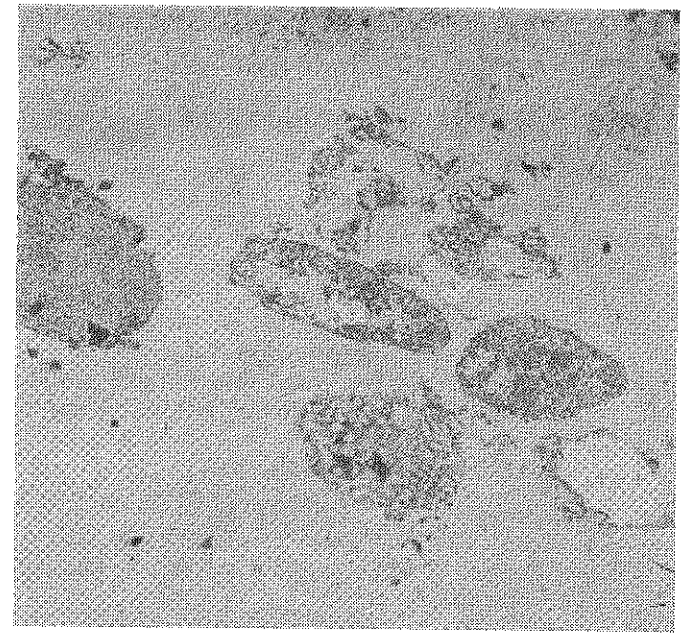

Figure 5. Electron micrograph of isolated maize nuclei. Magnification: X 5400.

The isolation methods described in this report were also used for extensive studies of fractionated maize seedling chromatin and its components (results not shown). Isolated chromatin was fractionated using DNase II digestion and $Mg^{2+}$-precipitation (28, 29). Digestion kinetics were studied, and fractions obtained were analyzed for DNA, RNA, and protein ratios. Migration patterns of histones and nonhistone chromosomal proteins were obtained by sodium dodecyl sulfate polyacrylamide gel electrophoresis. A class of nonhistones which resemble high mobility group (HMG) proteins was also found. These results will be published elsewhere. Therefore, all results indicate that nuclei and chromatin isolated by the described methods will provide an adequate starting material for the further study of maize seedling chromatin.

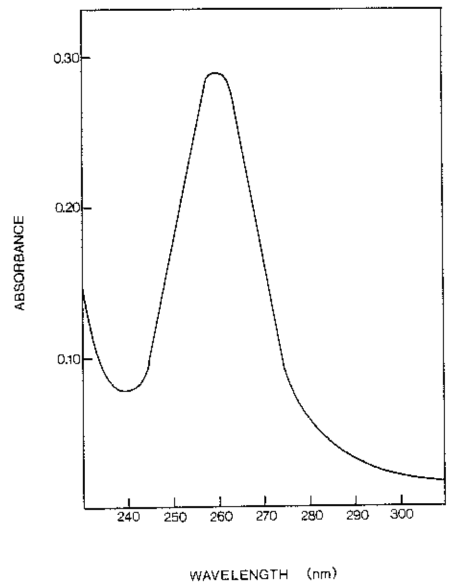


Figure 6. UV absorption spectrum of isolated maize seedling chromatin. Chromatin was prepared as described in the Experimental Methods section, and was suspended in 25 mM sodium acetate, pH 6.6.

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# Ecology Section

## A "Sequential Strategy" in the Respiratory Response to Hypoxia of the Green Crab, *Carcinus maenas* (L.) (Decapoda: Portunidae)


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### Abstract

The respiratory response of *Carcinus maenas* to progressive hypoxia was examined. At an environmental $P_{O_2}$ level of 64.8 ± 14.5 torr, these crabs protrude their carapaces into the air (emersion response); at 22.7 ± 4.4 torr they cease ventilation and shift to anaerobic metabolism.

In *Carcinus maenas*, emersion and aerobic shutdown are used as a "sequential strategy" for dealing with environmental hypoxia. The more ATP-efficient emersion strategy is utilized under normoxic conditions, but aerobic shutdown is adopted if the atmosphere is anoxic, if emersion is precluded, or if it is negatively reinforced.

## Introduction

*Carcinus maenas* (L.), the green crab, encounters severely hypoxic conditions in its intertidal habitat (Naylor, 1962). Bohn (1897) first reported emersion behavior in *Carcinus* as a response to hypoxic conditions and Borradaile (1922) described the mechanism of emersing the anterior margin of the carapace, reversing scaphagnothite beat, and ventilating the branchial chambers with air. As long as the gills remain moist, adequate respiratory gas exchange can occur in air. The ventilatory activity of *Carcinus* is more intense in air than in water (Ivlev and Sushchenya, 1960). Also, the total uptake of oxygen is less in air than in water (Wallace, 1972) resulting in respiratory acidosis, caused by a marked increase in $P_{CO_2}$ following emersion (Truchot, 1975).

Emersion behavior studies have shown that emersion occurs at that critical $P_{O_2}$ value above which the animal can regulate its oxygen consumption rate ($\dot{V}_{O_2}$) and below which it must conform (Taylor et al., 1973). Below this critical value ($P_C$), bradycardia develops and cardiac output declines during hypoxia. The $P_C$ for *Carcinus* also increases with environmental temperature (Taylor et al., 1977), and emersion may represent a strategy used to avoid hypoxia and to reduce oxygen demand by cooling the tissues (Taylor and Wheatly, 1979).

Burke (1979) studied both aerobic and anaerobic metabolism in *Carcinus* during hypoxia and reported that as environmental $P_{O_2}$ decreases below the $P_C$, where $\dot{V}_{O_2}$ decreases, lactate production increases. Burke proposed that anaerobic metabolism may play an important role in "maintaining a normoxic metabolic rate" during hypoxia in *Carcinus*. Lactate also increases the oxygen affinity of *Carcinus* hemocyanin (Truchot, 1980) and might be of use in aerobic metabolism.

*Carcinus* is capable of aerobic shutdown during environmental hypoxia (Becker and Bayne, 1976; Burke, 1979) i. e., the total cessation of $\dot{V}_{O_2}$, accompanied by a shift to anaerobic metabolism. Aerobic shutdown occurs at low $P_{O_2}$ levels relative to the $P_C$ at which emersion occurs.



Since aerobic pathways are more ATP-efficient than anaerobic ones, and intertidal habitats are generally shallow enough to allow for emersion, the question arises whether aerobic shutdown is a strategy commonly adopted in nature.

To answer this question, $\dot{V}_{O_2}$ levels were measured in *Carcinus* during progressive hypoxia under various conditions of accessibility to a normoxic atmosphere.

## Materials and Methods

*Carcinus maenas* were obtained from the Marine Biological Laboratory, Woods Hole, MA. The animals ranged from 6 to 10 cm in carapace width in about equal numbers of males and females. They were held in a 250 liter recirculating synthetic sea water table at 14$^{o}$ C and 25 o/oo S. For long-term maintenance, the crabs were fed chopped beef heart every three days (Ponat and Adelung, 1980). They were not fed for at least 14 days prior to testing in order to dampen tidal and diel rhythms of $\dot{V}_{O}$ (Arudpragasam and Naylor, 1964) and to eliminate variation in metabolic rate related to digestive activity (Wallace. 1973).

The respirometers, which were similar to those used by Bayne (1971), held one liter of water. The animal rested on a perforated glass plate above a magnetic stirring unit to ensure a uniform $P_{O_2}$ distribution throughout the chamber. The respirometer was submerged in a thermostatically-controlled water bath at 14$^{o}$C. At 30 minute intervals, a 50 ul sample of water was withdrawn by syringe. The $P_{O_2}$ was determined using a Radiometer type E-5046 oxygen electrode with a Radiometer PHM 71-Mk2 acid-base analyzer.

Each animal was allowed to deplete the oxygen in the chamber and the $P_{O_2}$ levels were recorded at both the initiation time of emersion behavior and at aerobic shutdown (operationally defined as the environmental $P_{O_2}$ at which the rate of $O_2$ utilization fell to less than 1 torr per hour).

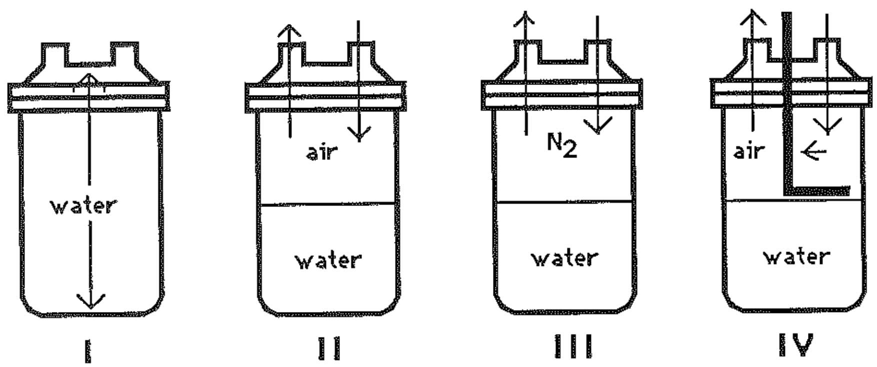


Figure 1. Illustrations of the four test conditions: I = no atmosphere, II = normoxic atmosphere, III = anoxic atmosphere, and IV = negative reinforcement of emersion behavior

The experiments consisted of four test conditions with 10 animals tested in each condition. The test conditions represented various degrees of accessibility to a normoxic atmosphere (Figure 1). In condition I, the chamber was filled with sea water, thus precluding aerial respiration. In condition II, 600 ml of sea water were placed in the chamber, allowing 400 ml of normoxic air above the water surface. In condition III, 600 ml of sea water were placed in the chamber and a continuous flow of nitrogen was maintained through the space above the water surface. Although the $P_{O_2}$ dropped as $O_2$ was lost to the $N_2$ atmosphere, the decrease was slow enough so that aerobic shutdown for each crab could be determined. In condition IV, a normoxic atmosphere identical to condition II was established and, in addition, a length of flexible tubing was rotated (c. 50 rpm) several mm above the water surface. The tubing was sufficiently pliable that it could strike an emersed carapace without physically causing re-immersion, but it was clearly an effective negative reinforcement (Becker and Valinski, 1981).

## Results

*Carcinus* emersed at an overall mean environmental $P_{O_2}$ of 64.8 ± 14.5 torr ($\bar{X} \pm s$). The lowest $P_{O_2}$ for emersion (58.7 ± 17.9 torr) occurred under condition I. For condition II emersion occurred at 64.9 ± 16.1 torr, in condition II at 66.3 ± 10.8 torr, and in condition IV at 69.2 ± 13.3 torr. There were no differences among the means of the four conditions (F = 1.17, using an analysis of variance).

The emersion behavior involved a high level of physical activity including climbing and rapid scaphagnothite and antennule activity. This behavior persisted for 15 to 45 minutes and was accompanied by a rapid decrease in the $P_{O_2}$ of the water. In general, emersion behavior terminated abruptly with the animal resting on the base of the respirometer and ceasing all obvious activity except scaphagnothite and antennule beating.

Aerobic shutdown occurred at a $P_{O_2}$ of 22.7 ± 4.4 torr ($\bar{X} \pm s$). *Carcinus*, exposed to conditions I, III, and IV, ceased oxygen consumption at 22.8 ± 4.2, 23.1 ± 4.7, and 22.4 ± 2.9 torr, respectively. (The means of the three test conditions were not different; F = 0.82, using an analysis of variance). Aerobic shutdown did not occur in condition II, since a normoxic atmosphere existed over the water surface. Rather, the animals remained emersed and continued aerial respiration. There was no association found between the emersion and shutdown $P_{O_2}$ levels.

## Discussion

Condition II is essentialy a control since as aquatic hypoxia progresses, *Carcinus* emerse, initiate aerial respiration, and continue aerobic metabolism. The $P_{O_2}$ value at which emersion occurred in these experiments (65 torr) generally agrees with those of Taylor et al. (1973) of 59 torr at 17° C and those of Burke (1979), of 50 - 60 torr at 15° C. The relatively large variation of emersion $P_{O_2}$ is consistent with the findings of Taylor et al. (1977) that the $P_C$ in *Carcinus* is much less well defined than those for most other organisms. The transition from respiratory regulation to conformity is accompanied by a rise in hemolymph $P_{CO_2}$. Since this rise is relatively rapid during emersion (Taylor and Wheatly, 1979), and since the $CO_2$ dissociation curves for *Carcinus* are much steeper at intermolt and premolt stages (when blood protein concentrations are higher that at postmolt; Truchot, 1976), the results suggest that $P_C$ may well be affected by the molting condition.

Below $P_C$ *Carcinus* demonstrates a marked bradycardia (Taylor et al., 1973) and, as hypoxia progresses, $O_2$ extraction efficiency, ventilation rate, and cardiac output decreases. Therefore, the abrupt cessation of activity following the termination of emersion behavior is related to the generalized decrease in metabolic rate due to the transition to respiratory conformity. The $P_{O_2}$ at aerobic shutdown ($22.7 \pm 4.4$ torr) is comparable to that reported by Burke (1979) of between 10 and 25 torr.

The oxygen gradient of the three test conditions, (I, III, and IV) range from no atmosphere (I), to an anoxic atmosphere (III), to a normoxic (but "dangerous[1]") atmosphere (IV). Conditions I and III may be considered together as functionally precluding the possibility of aerial aerobic respiration. Condition IV differs from I and III in that, although negatively reinforced, continued emersion behavior into a normoxic atmosphere is a possible alternative to aerobic shutdown and its concomitant anaerobic metabolism. Therefore, the similarity of responses in all three cases indicates that aerobic shutdown is not an artifact of experimental methodology, but rather a strategy that can be employed as an alternative to emersion. Naturally encountered situations comparable to the test conditions are likely to be found in marshes. In these areas, although emersion is possible, the atmosphere at the water surface may be anoxic due to ammonia, methane, or hydrogen sulfide production (similar to condition III). Similarly, avian predation pressure on the crabs could be particularly intense, thus negatively reinforcing emersion as simulated in condition IV. Finally, the crabs may be in water too deep from which to emerse (similar to condition I).

In conclusion, the combination of emersion and aerobic shutdown in *Carcinus* represents the availability of a "sequential strategy" for dealing with environmental hypoxia ((1) aquatic aerobic ---> (2) aerial aerobic ---> (3) anaerobic and only where 2 is impossible, unprofitable, or unwise do they shift to 3). If a normoxic atmosphere is available and can be accessed safely, *Carcinus* adopts an emersion strategy, taking advantage of more ATP-efficient aerobic metabolic pathways. However, if a normoxic atmosphere is unavailable or unsafe, *Carcinus* can and does resort to the strategy of aerobic shutdown.

[1] By "dangerous" we refer to the risk of some detrimental event, such as predation.



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# The Golden Mouse ( *Ochrotomys nuttalli*) in West Virginia

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## Abstract

Records of the Golden Mouse, *Ochrotomys nuttalli*, are reported from Lincoln, Mercer, and Wayne counties. Previously, the species was known only from Cabell and McDowell counties. External and cranial measurements of 15 specimens from WV and 5 from South Carolina are compared with those of 20 specimens of *Peromyscus leucopus*. Most mean measurements of West Virginia specimens of *O. nuttalli* are larger than those of the more southern specimens. The skull of Golden Mouse is robust, characterized by greater mean interorbital, mastoidal and zygomatic widths. *O. nuttalli* can be distinguished from *P. leucopus* in the field by its distinctly tawny-colored rather than grayish-brown ears.

## Introduction

The Golden Mouse, *Ochrotomys nuttalli*, is among several species of special concern listed by the WV DNR Nongame Program. It was described as *Arvicola nuttalli* by Harlan in 1832 from the type locality, Norfolk, Norfolk Co., Virginia. The species was later placed in the genus *Peromyscus* by Troussart. Subgeneric status was accorded with a description of *Ochrotomys* (Osgood, 1909). Hooper (1958) recognized the taxon as a distinct genus, a decision supported by much evidence accumulated since then.

The geographic range of the species is the southeastern United States. The distribution closely corresponds to that of the eastern deciduous (oak-hickory) hardwood and pine forests (Hall, 1981). Although suitable habitat appears to exist in much of West Virginia, *Ochrotomys nuttalli* was not reported as part of the fauna until 1970 (Lilly, et al., 1970; Dotson & Griffith, 1970).

This report of our preliminary study of *Ochrotomys nuttalli* from West Virginia summarizes the known distribution and ecology of *Ochrotomys nuttalli* in the state and reports new locality records; it also includes data on the external and cranial morphology of the known West Virginia specimens of *O. nuttalli* with comparisons to a sample of the species from South Carolina and another sample of West Virginia *Peromyscus leucopus.*

**Methods and Materials**

All known specimens of *O. nuttalli* collected in West Virginia (Table 1.) were examined. The specimens from Mercer and Lincoln counties are in the holdings of Carnegie Museum of Natural History (CMNH). The Lincoln and Cabell county specimens and the McDowell county specimen collected by the late Professor Bibbee are part of the Marshall University research collection (MUMC). Only adult specimens were used for cranial analyses. One of the animals, a young female captured in Wayne county in October 1987 is in captivity for observations.

Table 1. West Virginia Specimens of *Ochrotomys nuttalli*

| County | Number | Date Collected | Reference |
|---|---|---|---|
| McDowell | (1 ?) | 1948, | P. C. Bibbee |
| Cabell | (2 F, 1 M) | 1968, | Dotson & Griffith, 1970 |
| Mercer | (1 M) | 1986, | D. LeBlanc, Carnegie Mus. Nat. Hist. |
| Lincoln | (3 F, 4 M) | 1952, | Frum, Marshall Univ., this paper. |
| Wayne | (1 F, 3 M) | 1975, | D. Blue & L. McCallister, this paper. |
| | | 1987, | J. K. Fletcher, this paper. |



Table 2. Mean Standard Measurements.

| External Measurements (mm) | O. n. (15 WV) | O. n. (5 SC) | O. n. (all) | P. l. (20 WV) |
|---|---|---|---|---|
| Total Length | 173 | 166 | 171 | 169 |
| Tail Length | 82 | 77 | 80 | 80 |
| Hind Foot | 20 | 17 | 19 | 21 |
| Ear | 17 | 18 | 18 | 17 |

Five adult specimens of *Ochrotomys nuttalli* from South Carolina (CMNH) and 20 adult specimens of *Peromyscus leucopus* from Cabell, Wayne, Lincoln, McDowell, and Mercer counties (MUMC) were used for comparisons.

Table 3. Means of cranial measurements.

| Characters (mm) | O. n. (15 WV) | O. n. (5SC) | O. n. (all) | P. l. (20 WV) |
|---|---|---|---|---|
| Greatest Length | 26.1 | 23.3 | 25.4 | 25.9 |
| Condylobasal Length | 23.9 | 22.4 | 23.4 | 23.2 |
| Zygomatic Breadth | 13.7 | 13.2 | 13.6 | 13.1 |
| Interorbital Breadth | 4.4 | 4.1 | 4.3 | 3.9 |
| Mastoid Breadth | 11.1 | 11.4 | 11.2 | 10.9 |
| Tooth Row Length | 3.9 | 3.8 | 3.8 | 3.5 |
| Cranial Depth | 9.8 | 9.4 | 9.8 | 9.4 |
| Molar Breadth | 5.0 | 4.8 | 4.9 | 4.7 |

Four standard external measurements (total length, tail length, hind foot length and ear length) were taken from the specimen tags (Table 2). Mensural data were taken for eight commonly used cranial characters: Greatest length, condylobasal length, zygomatic breadth, interorbital breadth, mastoid breadth, tooth row length, molar width, and greatest cranial depth, all as defined and illustrated by Packard (1960). Cranial measurements were made using Helios needlepoint calipers to the nearest 0.5 mm. Secondary sex variation was insignificant and data were grouped for calculating standard statistics (Table 5).

## Results and Discussion

The habitat of Golden mice in West Virginia appears to be low elevation wooded areas, especially thickets close to stands of pines and hardwoods. The mouse has been found only in or near a thick understory of honeysuckle, greenbrier, blackberry or Rhododendron. Although we trapped presumably appropriate habitat in other southern West Virginia counties (Monroe, Summers, Fayette, Raleigh, and Kanawha) in 1986 and 1987, we found no additional populations. We suspect that the occurrence of Golden mice in this state may be influenced by the density of the White-footed Mouse, shown to be a competitor for resources in Tennessee studies (Deuser and Shurgart, 1978; Seagle, 1985).

Golden mice are not known to hibernate anywhere in their geographic range. They have been collected at elevations of less than 300 meters in every month except July, August and December.

*Ochrotomys nuttalli* is arboreal and has a semi-prehensile tail; the feet are smaller than those of *Peromyscus* species of comparable size. Nests are among branches of small trees or shrubs, usually 1.5 to 4.5 meters above ground, but sometimes higher. They are constructed of shredded plant fibers and leaves, and lined with soft materials such as mammal fur or bird feathers. A typical nest was found in Wayne Co. last fall approximately 2 meters above the ground, tucked into a tangle of honeysuckle.

Superficially similar in appearance and size to the ubiquitous White-footed Mouse, *Peromyscus leucopus*, the Golden Mouse has a brighter tawny upper pelage; underparts and feet are creamy, with an ocherous wash, and the side line is indistinct. The tail is faintly bicolored. Dorsal coloration of *P. leucopus* tends to be more brownish with a distinct side line with white ventrum and feet. The best single field character for distinguishing the Golden Mouse from the White-footed mouse is its tawny or golden (instead of grayish) colored ears.

External measurements (Table 2.) do not readily separate *Ochrotomys nuttalli* from *Peromyscus leucopus*. As reported for this arboreal species from other states (Packard, 1968) we found the feet to be relatively small. Golden Mouse ear and hind foot lengths are slightly closer in value to each other than those of *P. leucopus*. Overall, body size of *Ochrotomys nuttalli* from West Virginia appears larger than from South Carolina, although this effect may be exaggerated by the small sample. In his study of geographic variation in the species, Packard (1968) reported a cline of decreasing size of external and cranial characters from the Appalachian Mountains southward.

Cranial measurements of West Virginia *Ochrotomys* and southern specimens were more similar than the external measurements, but the trend to smaller size in the southern specimens persisted (Table 3). When compared to *Peromyscus leucopus*, the *Ochrotomys* skull seems somewhat more robust in some cranial measurements (zygomatic, mastoid, and interorbital breadths). Except for overall skull length and condylobasal length, the West Virginia *Ochrotomys* skull is, on average, distinctly larger than the skull of *P. leucopus*. The position of the lateral margins of the infraorbital foramina, concealed by the zygomata in dorsal aspect, is characteristic of the *Ochrotomys* skull and useful in identification (W. Gene Frum, personal communication to MEH). Among the *Ochrotomys* specimens in our sample the variance in all characters was very low.


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# Discriminating Degree of White-Tailed Deer Travel Route Use

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## Abstract

Five environmental parameters were measured and recorded concerning White-tailed Deer (*Odocileus virginianus*) travel routes. Quantification of such travel use may be useful in wildlife management, such as timber harvesting operations. The parameters included number of browse, per cent grass and forbs, average slope, percent overstory coverage, and distance of the travel route to the nearest road. Contacts were developed between 44 samples of known deer use and 44 samples on known non-deer use areas. These samples were randomly sampled along trails and transects. A total of 23 statistical hypotheses were tested using multiple linear regression techniques, corrected for multiple comparisons. Sixteen of these hypotheses were found to be significant. All five independent variables accounted for 29.2 percent of the explained variance in discriminating deer use. The model containing only browse and overstory coverage accounted for most (94.5 per cent) of this total variance. Results from the Spearman and Kendall nonparametric correlations ranked browse and overstory coverage as adding most to explained variance. The best regression equation, according to forward stepwise procedures, yielded browse and overstory parameters as well. In addition, covariance procedures yielded negligible effects of multicolinearity on the hypotheses-testing results.

## Introduction

Land developers and environmental managers need a more comprehensive data base concerning the types of wildlife and their habitat requirements in order to make intelligent decisions about land use. This creation of databases is particularly true for the white-tailed deer (*Odocoileus virginianus*).

The travel routes of this deer provide important input concerning the potential location of housing developments, agricultural production, and general industrial use. For example, the timber industry may be able to utilize the existence of travel routes to determine the location of timber harvesting operations. If, for illustration purposes, two stands of timber are equally ready to be harvested, the degree of damage to the deer population of one stand versus another may influence which stand will be harvested. One stand may be used exclusively by the deer population in the area as a means of ingress or egress to feeding or sheltering grounds. The other stand may be rarely used by deer. Therefore, in this situation, the resource manager needs some method of predicting the impact of the timber operations on deer migrations. Since stands of timber commonly take 30 to 40 years to regenerate, the long term effects on the deer population may be disastrous and it may be difficult to repair the damages to the deer population.

With these effects in mind, the objective is to characterize travel routes that deer use compared to relative nonuse. By the quantification of travel routes to feeding and safety areas, predictive equations may offer decision tools for resource managers. Unfortunately, several attempts to develop these predictive equations have met with limited success (1-7). Much controversy has developed over the factors that constitute deer use.

According to Weber et at. (2), similar areas under study were classified as to presence or absence of deer use. This comprehensive research effort attempted to classify areas of deer use by the measurement of 119 variables. However, only three out of 119 parameters were found to statistically discriminate degree of deer use, namely amount of browse (food source), overstory coverage, and average slope. The goal of the present research is to extend Weber's research to areas of extensive versus absence of deer use.



## Methods

A total of five environmental variable selection and data collection parameters were included in the present research effort to discriminate degree of deer use. These variables were found to be relatively important in the literature and include number of browse, grass and forbs, average slope, overstory coverage, and distance to the nearest road. The study area is located in North Park, a major wildlife and recreational area in Allegheny County, southwestern Pennsylvania. As a result of future plans in the area for extensive tree harvesting, predictive tools are needed for resource planning and proper management of the large white-tailed deer population. In addition, the results of this study would have applications through the Appalachian areas, including sections of Ohio, Kentucky, Tennessee, and West Virginia.

Table 1. Summary of independent variables, variance explained ($R^2$), degrees of freedom (df), F-ratio, and statistical significance at the 0.05 level in the discrimination of deer use.

| Independent Variable(s) | $R^2$ | df | F-Ratio | Significance |
|---|---|---|---|---|
| BROWSE, GRASS, SLOPE OVERSTORY, ROAD | 0.29246 | 5/82 | 6.77901 | S |
| BROWSE | 0.18353 | 1/86 | 19.33151 | S |
| GRASS | 0.00014 | 1/86 | 0.01184 | NS |
| SLOPE | 0.01496 | 1/86 | 1.30626 | NS |
| OVERSTORY | 0.16218 | 1/86 | 16.6470 | S |
| ROAD | 0.00089 | 1/86 | 0.07698 | NS |
| BROWSE, GRASS | 0.20175 | 2/85 | 10.74150 | S |
| BROWSE, GRASS, SLOPE | 0.21386 | 3/84 | 7.61711 | S |
| BROWSE, GRASS, SLOPE OVERSTORY | 0.29004 | 4/83 | 8.47705 | S |
| BROWSE, SLOPE, OVERSTORY | 0.28716 | 3/84 | 11.27958 | S |

Table 1. Cont.

| Independent Variable(s) | $R^2$ | df | F-Ratio | Significance |
|---|---|---|---|---|
| GRASS, SLOPE, OVERSTORY, ROAD | 0.17986 | 4/83 | 4.55056 | NS |
| BROWSE, SLOPE, OVERSTORY ROAD | 0.29050 | 4/83 | 8.49595 | S |
| BROWSE, GRASS, OVERSTORY ROAD | 0.28414 | 4/83 | 8.23627 | S |
| BROWSE, GRASS, SLOPE ROAD | 0.21940 | 4/83 | 5.83196 | S |
| BROWSE, SLOPE | 0.19668 | 2/85 | 10.40567 | S |
| BROWSE, OVERSTORY | 0.27641 | 2/85 | 16.23492 | S |
| BROWSE, ROAD | 0.19734 | 2/85 | 10.48180 | S |
| GRASS, SLOPE | 0.01519 | 2/85 | 0.65547 | NS |
| GRASS, OVERSTORY | 0.16815 | 2/85 | 8.59099 | S |
| GRASS, ROAD | 0.00130 | 2/85 | 0.05521 | NS |
| SLOPE, OVERSTORY | 0.17351 | 2/85 | 8.92213 | S |
| SLOPE, ROAD | 0.01502 | 2/85 | 0.64798 | NS |
| OVERSTORY, ROAD | 0.16220 | 2/85 | 8.22807 | S |

*Note:* An F-test was used to test for statistically significant relationships. The two-tailed, nondirectional test using alpha of 0.05 was used. The corrected level for multiple comparisons employing Newman and Fry's (10) method is 0.001 for individual comparisons.

The forested tracks of the park are approximately 60 per cent mature Scotch Pine (*Pinus sylvestris*) and 40 per cent oak-maple complexes (*Quercus spec., Acer spec.*). The forested areas were divided into two major groups: group one containing the oak-maple complexes and exhibiting visible signs of deer use; and group two, also of the oak-maple complexes, but with negligible or no signs of deer use. The primary indicators of deer use were the presence of deer fecal pellet groupings, deer tracks, and trails which exhibited a worn depression in the ground that can be attributed to deer usage. If any combination of these factors was present, a sample plot was placed in the deer use area. If none of these indicators were present in the plot, then a plot was established to identify with the non-deer use areas. The size of the plots, following standard practice (4), was a circle of a 12 foot radius. Deer trails were systematically located throughout the areas of non-deer use (i.e. group two). A total of 44 plots was established by griding the area along trails and transects to randomly select the sample. The total number of plots for each group was 44. This figure was calculated via power analysis and theoretical validity considerations (8, 9). During the data collection phase attempts were made to ensure that only well-established trails that represented classic throughways for the deer population were included in the study. For example, if a trail forked into multiple trails, only the most highly used trail was followed. This was determined by the presence or absence of deer tracks in either fork of the trail. All five independent variables were measured at each randomly selected plot.

Standard procedures were generally followed in the collection of each independent parameter. The number of browse species that are available for the deer to consume during the summer season, 1985, was determined by techniques suggested by Nudds (5) and Shafer (6). The per cent of grass and forbs was estimated by visible inspection. The average slope was obtained by averaging forward and backward clinometer readings on the trails in the deer use group. The clinometer readings were taken forward and backward on the transects, then averaged to arrive at slope figures for the non-deer use group. Thus, by taking the averages in this way, the readings were on the line of projected travel for both groups. The per cent overstory coverage was calculated by utilizing a 100 square grid on transparent plastic held up to the line of sight (2, 4). The distance to the nearest road was simply derived from the map for every plot location.

### Statistical Techniques

Multiple linear regression, forward stepwise regression, full and restricted model concepts, corrections for multiple comparisons, and covariance procedures were completed on the data to determine discriminative functions of deer use between the two major groups. In addition to the statistical techniques employed during the hypothesis-testing phase of the study, nonparametric correlations, namely Spearman and Kendall, were calculated. The decision to use nonparametric instead of the parametric Pearson Product-Moment correlation, was based on the kurtosis and skewness values for the independent parameters. Those results, which are discussed in the next section, provided evidence that the normal distribution function may not be applicable to the results of the data collection. However, the F-test used in conjunction with the regression procedures is generally least sensitive to violations of normality and, hence, used in the final analysis of the data.

## Results

Table 2. Summary of regression weights involved in the model building process via forward stepwise regression and results derived from Table 1.

| Number of variables in model | $R^2$ | Independent variables | Regression weights |
|---|---|---|---|
| 2 | 0.276 | BROWSE | 0.00847 |
| | | OVERSTORY | 0.01518 |
| | | CONSTANT* | -1.14789 |
| 3 | 0.287 | BROWSE | 0.00845 |
| | | OVERSTORY | 0.01499 |
| | | SLOPE | 0.00570 |
| | | CONSTANT | -1.02681 |
| 4 | 0.290 | BROWSE | 0.00881 |
| | | OVERSTORY | 0.01458 |
| | | SLOPE | 0.00509 |
| | | ROAD | 0.00439 |
| | | CONSTANT | -1.07286 |

*Denotes intercept or constant term in the best fitted regression equation using the least sum of squares criterion.

### *Hypothesis-Testing Results*

Tables 1 through 5 illustrate the results of the hypothesis-testing, Table 6 presents the descriptive statistics, and Table 7 is the summary of cross-validation procedures to determine if concurrent validity exists for the present data base. The major statistical findings are summarized in Table 1. A total of twenty-three hypotheses were tested, with sixteen being statistically significant at an alpha level of 0.05, once corrected for multiple comparisons (10). The full model, the model with all five of the independent variables, accounted for the highest variance explained in discriminating deer use ($R^2$ = 0.292). The single predictor of deer use was browse (p = 0.0000, $R^2$ = 0.183). The next factor to account for most variance in deer use was overstory coverage (p = 0.0001, $R^2$ = 0.162). The other three parameters of per cent grass and forbs, average slope, and distance to the nearest road, according to forward step regression techniques (Table 2), were not statistically significant predictors when tested in the one-variable models. The hypothesis-testing procedure yields seven significant equations with two independent parameters. However, the best two-variable model contains browse and overstory coverage, as shown in Table 2 with the corresponding regression weights ($R^2$ = 0.276). The best three-variable model was determined to be composed of browse, average slope, and overstory coverage ($R^2$ = 0.287) (Table 2). Of the four models that were tested with four variables, the best predictive equation consisted of browse, average slope, overstory coverage, and distance to the nearest road.

### *Nonparametric Correlation Analysis*

The results of the nonparametric correlations are summarized in Tables 3 and 4. The Spearman coefficient for browse and deer use is 0.3694. Based on this correlation, browse accounted for approximately 13.6 per cent of the variation in deer use (p = 0.001). The Kendall Correlation for browse and deer use is 0.3068. This was found to be highly significant (p = 0.001). The correlation between overstory coverage and deer use accounted for the lowest Type I error. The corresponding Spearman and Kendall Correlations are 0.5142 and 0.4305, respectively. Based on the nonparametric correlation, browse and overstory coverage are the only independent variables that were found to be highly correlated (p = 0.01) with the deer use.

Table 3. Spearman correlation coefficients of selected variables.

| Parameters | Browse | Grass | Slope | Overstory | Road | Deer Use |
|---|---|---|---|---|---|---|
| BROWSE | 1.0000 | 0.2967 | 0.0392 | 0.2693* | -0.4630 | 0.3694** |
| GRASS | | 1.0000 | -0.0501 | -0.1413 | -0.2414 | -0.0705 |
| SLOPE | | | 1.0000 | 0.1065 | 0.1978 | 0.1100 |
| OVERSTORY | | | | 1.0000 | 0.1015 | 0.5142** |
| ROAD | | | | | 1.0000 | 0.0063 |
| DEER USE | | | | | | 1.0000 |

*Denotes statistical significance at the 0.05 alpha level for a two-tailed nondirectional test (correcte alpha = 0.01).
**Denotes high statistical significance at the 0.01 alpha level for a two-tailed nondirectional test (corrected alpha = 0.002)

Table 4. Kendall correlation coefficients of selected variables.

| Parameters | Browse | Grass | Slope | Overstory | Road | Deer Use |
|---|---|---|---|---|---|---|
| BROWSE | 1.0000 | 0.2239* | 0.0155 | 0.1882* | -0.0297 | 0.3068** |
| GRASS | | 1.0000 | -0.0321 | 0.0744 | 0.1328 | 0.0621 |
| SLOPE | | | 1.0000 | 0.0744 | 0.1328 | 0.0920 |
| OVERSTORY | | | | 1.0000 | 0.0734 | 0.4305** |
| ROAD | | | | | 1.0000 | 0.0052 |
| DEER USE | | | | | | 1.0000 |

*Denotes statistical significance at alpha level of 0.05 for a two-tailed, nondirectional test (corrected for multiple comparisons = 0.01).
**Denotes highly statistical significance at alpha level of 0.01 for a two-tailed, nondirectional test (corrected for multiple comparisons = 0.001).



Table 5. Summary results for each of the five independent variables regressed on deer use.

| Covariate | Source of variation | df | F Ratio | Significance |
|---|---|---|---|---|
| BROWSE | Full*<br>Restricted** | 1<br>82 | 133.3369 | S |
| GRASS | Full<br>Restricted | 1<br>82 | 82.5541 | S |
| SLOPE | Full<br>Restricted | 1<br>82 | 82.4009 | S |
| OVERSTORY | Full<br>Restricted | 1<br>82 | 109.3093 | S |
| ROAD | Full<br>Restricted | 1<br>82 | 82.6846 | S |

*Denotes full model, containing all the terms used in the initial regression model. In this case, the model includes Browse, Grass, Slope, Overstory, and Road.
**Denotes restricted model, containing the variables of the full model with the assumption that the full model is true. In this ease, the model includes Grass, Slope, Overstory, and Road.

*Covariance Analysis*

In addition, selected variables and their corresponding models were covaried by using the full and restricted concepts of multiple linear regression. One of the purposes of the covariance procedure is to isolate the unique contribution of each independent variable's explained variance in discrimination of deer use. This process, thus, is an aid in determining the effects of multicollinearity. A summary of the covariance results are displayed in Table 5. As evident from an inspection of Table 5, all the independent variables (browse, grass, slope, overstory, and road distance) were highly significant once the contribution of the remaining parameters was held constant. The F-values are relatively large, ranging from 82.41 to 133.34, indicating the strength of the relationships found. Again, the parameters overstory and browse were found to be highly significant, with the highest F-values (109.31 and 133.34, respectively). Hence, the relative effects of multicollinearity have negligible impact on the main results of the hypothesis-testing procedures.

## Discussion and Conclusions

The best predictive equation in discriminating degree of deer use was the four-variable equation, as evident in Table 2 ($R^2 = 0.29$). This equation included number of browse, grass and forbs, overstory coverage, and average slope. However, the two-variable model containing browse and overstory coverage accounted for the most variances in discriminating deer use (R = 0.276). Hence, increased amounts of cover and browse provided the best evidence for deep use of a particular tract. These equations did not account for the total variation between the degrees of deep use and are of moderate value as a predictive tool for land and resource managers to qualify an area's potential deer use. However, these equations, especially the two-variable model, tend to add support to the conclusions of Weber et al. (2). Browse and overstory coverage tend to be considered as two of the most important characteristics associated with deer use.

The forward stepwise regression procedure entered the parameter browse first and was then followed by per cent overstory coverage. The results of the nonparametric correlations of the Spearman and Kendall coefficients differ slightly with the stepwise results. The amount of the correlations reversed the order of importance, with overstory coverage having a greater coefficient than browse. This difference, however, may not be statistically significant.

Overall, the results of the present study support the basic conclusion of the prior literature, in that browse and overstory coverage are important parameters in deciding degree of deer use. Obviously, other important variables that have local significance need to be included along with the amount of browse and overstory coverage in order to produce a satisfactory model. In addition, the measurement of sampling errors that could have been introduced in the identification of the deer trails need proper attention. Sometimes the trails were well used but covered by a mat of decaying hardwood leaves which masked the true extent of use by the deer population. However, as evident by the cross-validation procedure, the results of this study have concurrent validity and provide firm support for the use of number of browse and per cent overstory coverage in any predictive model regarding deer use.



Table 6. Descriptive statistics of the selected variables.

| Variable(s) | Mean | Skewness | Kurtosis |
|---|---|---|---|
| BROWSE | 24.85 | 1.653 | 2.329 |
| GRASS | 34.32 | 0.726 | -0.436 |
| SLOPE | -0.71 | 0.161 | -0.613 |
| OVERSTORY | 88.10 | -1.534 | 3.973 |
| ROAD | 165.62 | 0.380 | -0.478 |

Table 7. Cross-validation results testing the concurrent validity of the basic relationships found in the study.

Regression Equation of Full Model: (derived from first sample)

Deer Use = -0.87945 + 0.1055*BROWSE = -0.00130*Grass = + 0.00596 *SLOPE = + 0.01211*OVERSTORY = + 0.00424*ROAD

| Randomized sample | Sample Size | $R^2$ (Variance explained) |
|---|---|---|
| 1 | 74 | 0.24822 |
| 2 | 66 | 0.23151 |
| 3 | 69 | 0.27944 |

*Note:* Resultant $R^2$ difference is derived from the average of the $R^2$ s from the three samples minus the $R^2$ determined from applying the regression weights derived from the first sample to the data of another random sample, divided by the average $R^2$ of the samples. In general, if this change is less than 10 to 20 percent, concurrent validity can be asserted.

$$(0.25306 - 0.22795)/0.25306 = 0.09923$$

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# Geology Section

## Files Run Quarry (46RD114): Prehistoric Lithic Procurement and Reduction Strategy in Randolph County, West Virginia


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### Abstract

A source of Greenbrier chert utilized by prehistoric groups was discovered on the western slope of Cheat Mountain in Randolph County, West Virginia in May 1987. Greenbrier chert had been previously noted in artifact assemblages from the Tygart Valley and was first reported and described at the Limekiln Run Site (46RD97) in 1985 (Brashler and Lesser). No source location was found for the chert during the investigations at Limekiln Run, however.

Files Run Quarry (46RD114) is located 3.2 kilometers northeast of the Limekiln Run site and consists of exposed Greenbrier chert nodules, fragments, bifaces, and various categories of chert debitage on a 30 percent slope. This report presents the findings of a controlled surface sample taken at the site in 1987 and addresses site function and association with nearby Greenbrier chert reduction stations as part of a local settlement-subsistence model.


### Environmental Setting

The Files Run Quarry site lies at an elevation of 878 meters above sea level on the west slope of Cheat Mountain, approximately 8.8 kilometers east of Beverly, West Virginia. The site lies in that portion of the Allegheny Plateau characterized by narrow benches and steep slopes (Churchill and Tryon 1982).

The area has a mean annual precipitation of 106 to 122 centimeters. Modern mean annual temperature is 59 degrees Celsius. Recent vegetation in this zone is characterized by a northern hardwood forest including an oak-hickory association on drier locations and northern red oak, black cherry, ash and tulip poplar on the more moist soils. Prior to 1930, chestnut was also a common component of the drier sites in the area (Core 1966).

The Files Run Quarry site occurs just below the poorly exposed top of the Greenbrier Series limestone on the western face of Cheat Mountain. The site is on a side slope averaging approximately 30 percent. The site is bounded on the south by the headwaters of Files Run, a tributary of the Left Fork of Files Creek.

## Geology

The geology of the area in the vicinity of Files Run Quarry has been previously summarized from investigations at the Limekiln Run site, approximately 3.2 kilometers southwest (Brashler and Lesser 1985). Limekiln Run (46RD97) was used primarily for reduction and manufacturing of locally obtained Greenbrier chert, a previously undescribed black chert with distinctive sandy laminations. Greenbrier Series Limestone outcrops approximately 100 meters above the Limekiln Run site and it was originally believed that the chert was extracted or collected from the outcrop just above and carried below for reduction. No chert was found *in situ* at the outcrop, but the high percentage of Greenbrier chert (over 95%) and the occurrence of unmodified chert in various stream drainages originating in the area of the Greenbrier Series limestone strongly suggested that the chert occurred somewhere in the Greenbrier Series (Brashler and Lesser 1985:38). Discovery of the Files Run Quarry site finally revealed a source location for Greenbrier chert.

In this section of the Appalachian Plateau strata have been uplifted and eroded, resulting in benches formed by resistant sandstones and limestones occurring in the geological sequence. Stratigraphically, Greenbrier chert occurs as irregular nodules weathering from just below the top of the uppermost (Alderson) limestone of the Mississippian Greenbrier Series, less than 15 meters below the Mauch Chunk Series Webster Springs sandstone (Reger 1931).



## Field Investigations

The Files Run Quarry site was discovered by chance by the author on May 5, 1987. While walking the sideslope of Cheat Mountain, several exposed tabular pieces of Greenbrier chert were observed on the surface, not far above a prominent outcrop of Greenbrier Series limestone. Further investigation revealed many more pieces of chert, particularly in small bare areas resulting from various faunal feeding activity. Numerous pieces of Greenbrier chert were observed around the base of trees. The most striking aspect of the material at first was the large size of many of the pieces of chert, much larger than any previously examined in collections or in the field. Numerous cores, shatter, and chert flakes were also apparently represented. A large, nearly complete nodule of Greenbrier chert was soon found on the open sideslope.

Continued reconnaissance at the site in May and June, 1987 consisted of a walkover of the area in an attempt to define the limits of the site based on the exposure of surface chert. It was soon apparent that the site was linear in extent. The chert exposure was almost 200 meters long on a north-south axis roughly following the slope contour but only 60-80 meters east-west or downslope.

Based on the excellent ground visibility a research strategy was developed for further study. Use of a controlled surface collection was determined to be the best strategy to gather a representative collection of raw material (nodules) cores and other lithic debris from across the site. The purpose of this strategy was twofold in nature. First, it was hoped that a representative collection of surface lithic debris would enable us to reconstruct a lithic reduction sequence(s) for the site and to determine that it was, in fact, a quarry. Second, a controlled surface collection across the site should reveal artifact distributional differences indicative of differential use of site space. Information collected through this strategy could also be used to determine placement of subsurface testing units, if necessary.

For these purposes, a datum point and grid system were established across the site. The grid consisted of 20 ten meter squares, ten along the north-south baseline with a connecting series of ten to the east. The corners of each ten meter square were marked with wire survey flagging. The datum point for each square was the southwest corner.

A sampling strategy for the controlled surface collection was selected to collect all visible chert from each alternating east-west line of paired ten meter squares. Through this strategy, ten ten-meter squares were systematically surface collected on August 16 and 23, 1987. All visible chert was collected and bagged by unit, with three heavy concentrations of material bagged separately.

## Lithic Technology at Files Run Quarry

### *Analysis*

A total of 686 pieces of lithic debitage were collected from the ten ten-meter squares in the controlled surface collection at Files Run Quarry. Lithics were plentiful throughout the observed boundaries of the site. The lithic material recovered was analyzed to test the validity of the hypothesis that 46RD114 represented a quarry or extraction site and to determine the process by which raw material was modified at the site. The assemblage was examined with the aid of a ten power hand lens. The 686 pieces of debitage at the site were classified within 15 lithic categories. These range from a nearly complete nodule of Greenbrier chert over 30 centimeters in length to small reduction flakes.

The most obvious observation made during analysis of the Files Run Quarry assemblage is that it consists entirely of local Greenbrier chert. No other lithic types are represented.

Greenbrier chert has been previously described by Brashler and Lesser (1985). The distinctive linear banding and narrow range of color in Greenbrier chert give it distinctive physical characteristics. The chert ranges from fair to mediocre quality in terms of knapping quality. At the Files Run Quarry, it typically occurs in oval shaped modules of varying thickness with a well-developed cortical rind. Flaws and weathering fractures are abundant in the chert with resulting multitudes of blocky fragments or shatter.

Clearly, primary lithic reduction as represented by unworked raw material (nodules and fragments), cores, core fragments, primary decortication flakes, primary reduction flakes, angular shatter and angular shatter with cortex is dominant at the site. These categories comprise 92.9 percent of the total debitage. The percentage of secondary lithic reduction at the site, as represented by secondary reduction flakes and tertiary flakes, is 3.2 percent of the assemblage. Biface and biface fragments (including preforms) make up only 1.5 percent of the collection. Utilized/retouched flakes and shatter



represent the only obvious tool forms at Files Run Quarry and make up only 2.0 percent of the assemblage. Two possible hammerstones (.29 percent) were also recovered in the surface sample.

The percentages of lithic categories recovered in the surface collection at Files Run Quarry appear to be consistent with the assemblage expected at a quarry or extraction site. Based on the investigation at Files Run Quarry, it is likely that the chert nodules were simply spotted on the ground surface and reduced at the location of their discovery. Several depressions within the site area may be the result of limited digging by prehistoric groups to extract nodules when they were not otherwise available (cf. Odell 1984:54).

True quarrying, or actual excavation to locate and remove raw material from its geological matrix, is comparatively rare in the procurement of chert in the continental United States. The term "quarry" is used here as elsewhere in the archeological literature (Butler and May 1984:185) in a wider sense to denote an extractive location that was demonstrably the scene of long term or intensive activity.

Files Run Quarry is believed to be the first prehistoric quarry site to be systematically examined in West Virginia. In the Shenandoah Valley of Virginia, Gardner (1974:22) has defined the principle diagnostics of a quarry site as a preponderance of large size lithic debitage including cores, primary flakes and extremely crude bifaces; the almost complete absence of tools of any type; little or no evidence of patterning; and close proximity to an outcrop. Gardner states that quarry sites are limited purpose camps visited only for the extraction of raw material for removal to other areas.

Johnson (1984), in a study of prehistoric quarry site activity in northeastern Mississippi, reaffirms the observation of Holmes (1897) that activities represented in a quarry site assemblage depend on how the site articulates with the local prehistoric settlement system. Sites where quarrying is the only activity represented should contain debitage from only the early stages of lithic reduction, with a limited number of finished bifaces and other tools (Johnson 1984:231).

The Files Run Quarry assemblage fully meets the criteria of these definitions. The ten bifaces (preforms) and fragments recovered in the surface collection are, with the exception of one, very crude. The only tools recovered from the site are 14 utilized/retouched flakes and shatter, along with the two hammerstones.

## Lithic Reduction Sequence

Examination of the recovered nodules, cores and associated debitage from the controlled surface collection at Files Run Quarry indicates that the lithic reduction strategy at the site appears to have been rather simple and to have followed a definite pattern. Apparently Greenbrier chert nodules and large naturally split nodule fragments were being collected at the site and split up into smaller cores. Rounded edges of nodules appear to have been struck and broken off in order to prepare a striking platform from which to drive off cortex and primary flakes. This is the most commonly observed method of nodule reduction in prehistoric quarry assemblages (Binford and Papworth 1963:81). Examination of recovered cores indicates a relatively uniform and simple technology of flake production. Most cores can be assigned to an amorphous, multifacial type characterized by multiple discontinuous edges from which a few flakes were detached.

There is some evidence of the use of bipolar reduction techniques in the Files Run Quarry assemblage. This strategy would have been used most often on cores considered too small to reduce using the standard block core technique. This technique could also be used to make bifacial tools directly from a small bipolar core (Brashler and Lesser 1984; Holmes 1919).

The Files Run Quarry assemblage is noteworthy for the small percentage of reduction flakes recovered, in comparison with the Bass site, a quarry investigated in southwestern Wisconsin (Stoltman et al. 1984:206). This may be partly reflective of a sampling bias due to poor visibility of smaller reduction flakes at Files Run Quarry. However, it also appears that less core reduction took place at the site and that many smaller semi-prepared cores and crude bifaces were carried to nearby short-term habitation sites (reduction stations) where further tool reduction and other hunting and gathering activities took place.

## Site Chronology

No diagnostic artifacts were recovered at Files Run Quarry to aid in the determination of a site chronology. The lack of diagnostics is consistent with other investigated quarry sites discussed previously. Evidence of the use of Files Run Quarry during specific culture periods based on investigation of associated sites will be examined below.



## Synthesis

To truly understand the patterns presented in the above analysis, comparative data over a larger area must be examined. This approach focuses on the utilization of Greenbrier chert as a resource, considering its natural availability, procurement and route through human technological and economic systems. By nature of the assemblage, this is tied to the study of lithic technology. Due to a lack of associated data at area upland sites, lithic technology must be of primary emphasis (Lesser and Brashler 1987).

Greenbrier chert clearly represents a unique and important resource for prehistoric inhabitants of the area. Available cherts in this portion of the Appalachian Plateau are limited to Greenbrier Series limestone. Numerous other chert strata outcrop in the Ridge and Valley Province to the east, but the nearest source of these cherts is more than thirty miles away (Brashler, et al 1987). The only other reported chert source adjacent to the Tygart Valley is a "ledge of flint" near the head of Elkwater Fork in southern Randolph County supposedly discovered in the late 19th century (Maxwell 1898:285). This source has never been substantiated.

The relative importance of Greenbrier chert in local lithic assemblages has been previously examined by Brashler and Lesser (1985). Surface collections from six Tygart Valley River floodplain sites within a 9.5 kilometer radius of Files Run Quarry were analyzed. Most appeared to be multicomponent sites and all had projectile points made of Greenbrier chert. One large multicompónent site, 46RD64, had an assemblage of almost 400 projectile points recovered by a local collector over a decade. Projectile points of Greenbrier chert made up a little more than 15 percent of the collection and were represented in all culture periods except Paleo-Indian with the Late Archaic and Late Woodland seemingly best represented (Brashler and Lesser 1985:30). However, 52 percent of the recovered raw material and cores from this collection were Greenbrier chert. This suggests that prehistoric groups utilizing the Tygart Valley had access to various chert resources, though most of these sources were apparently some distance from the area.

During investigations at Files Run Quarry in 1987, another site located below and .9 kilometers northwest of the site was also examined. 46RD101, the Chenoweth/Files Divide site, was reported in 1985 (USDA Forest Service Monongahela National Forest Site Files). The site lies in the low gap divide of the Right Fork of Chenoweth Creek and Left Fork of Files Creek at an elevation of 813 meters a.s.l. 46RD101 has been heavily impacted by County Route 30 and two private access roads which intersect the site from the west and east.

Investigations at 46RD101 consisted of random surface collection in and adjacent to the exposed road surface in the low gap. A total of 107 artifacts were collected on three different dates from the site. Because of the unsystematic nature of the surface collection and its location in an active road bed, minute comparison with the artifact category percentages at the Limekiln Run site and Files Run Quarry would not be valid. However, several gross pattern observations may be made. As at Limekiln Run, more than 90 percent of the assemblage at 46RD101 is made of Greenbrier chert. The site also has a high percentage of cores and shatter, suggesting intensive lithic reduction activity. Like Limekiln Run, utilized flakes make up a significant part of the assemblage with several scrapers and projectile points represented. Bifaces and fragments are more plentiful at 46RD101, however. Two projectile points recovered at the site suggest a Late Archaic occupation dating to approximately 3500 B. C. (Wilkins 1985: Ritchie 1961).

Interestingly, access to the Files Run Quarry by the author was gained from the low gap or divide at 46RD101. From this point a relatively broad, gentle ridgetop was followed east before traversing the slope of Cheat Mountain south to the quarry. This ridgeline is a natural travel route between 46RD101 and Files Run Quarry, and artifacts recovered along it suggest that the route was used by prehistoric groups moving between the sites. Along with the artifact comparison discussed above, this also suggests that the two sites are related. 46RD101 appears to be a reduction station to where Greenbrier chert acquired at Files Run Quarry was carried and reduced. 46RD101 was probably a short-term occupation site, perhaps reoccupied over time, where other hunting and gathering activities were also conducted to some extent.

The previously mentioned Limekiln Run site (46RD97) was also a Greenbrier chert reduction station, apparently quite similar in form and function to 46RD101. Limekiln Run inhabitants may have visited Files Run Quarry for their lithic raw material but probably acquired Greenbrier chert from some other as yet undiscovered location in the Greenbrier Series limestone above and adjacent to the site. Diagnostic artifacts recovered from the site suggest a Late Archaic occupation.



This pattern of quarry site reduction of nodules to cores and crude bifaces (preforms), followed by their transport to adjacent habitation sites for further reduction to tools, has been noted previously by Schindler et al. (1982:536) among other researchers: (Sullivan and Rozen 1985:769; Ives 1984; Amick 1984; Gardner 1974; 1978; and Barber 1985.

The extensive use of Greenbrier chert for tools at floodplain sites in the Tygart Valley has already been documented (Brashler and Lesser 1985). Cores, unfinished bifaces or preforms, as well as finished tools, were likely transported from the reduction stations to downstream sites adjacent to or on the larger Tygart Valley River floodplain for final reduction and use. The surface assemblage at 46RD64 and other sites supports this. There should be a measurable regression in the percentage of Greenbrier chert in assemblages as one moves away from the quarry sources.

## Conclusion

The archaeological investigations at Files Run Quarry have revealed a source location for Greenbrier chert and prehistoric strategies for its reduction. The distinctive visual nature of the chert and the fact that it appears to be the only locally available chert source allow us to focus on its transport across the landscape to provide useful information on basic settlement-subsistence adaptation, resource utilization patterns, ranges of movement and social interaction and exchange. This paper has only begun to address these concerns. It is doubtful that the Files Run Quarry is unique. Other sources of Greenbrier chert likely exist along the top of the Greenbrier Series in the area. Some of these will no doubt reveal prehistoric quarry-extraction activity. Location and investigation of these and associated sites will aid in addressing questions and the formation of hypotheses relating to settlement and subsistence in the Tygart Valley uplands.

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# STATISTICAL EVALUATION OF FLOOR HEAVE CONDITION AND TIME OF FAILURE OF ROOF FALLS IN COAL MINES

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## Abstract

Two important coal-mining factors, namely floor heave and length of time that failure occurred after initial coal extraction, were statistically evaluated in a series of hypotheses. The independent failure criteria, such as sloughing of coal ribs, roof-bed characteristics, coal seam characteristics, pillar dimensions, and size factors of the roof fall itself, were examined. A total of 250 roof falls in five room-and-pillar coal mines in Pike, Martin, and Floyd counties of eastern Kentucky were inspected. The results of the hypotheses testing were: less time of the mine-roof fall occurrence after initial coal excavation was significantly associated with increased sloughing of coal ribs before failure of roof, less distance from the working face, and greater occurrence of mechanical-anchor bolts used for initial support as compared to full- or partial-column bolts; and increases presence of water and sloughing of ribs was significantly related to increased floor heave condition. In addition, frequency and descriptive statistics were used to create profiles of failure areas.

## Introduction

A multitude of factors must be considered in the successful underground coal-mine operation (1). Cost-sensitive mine planning systems have been developed to help coal companies design underground mines that will recover coal reserves in the most profitable method. Information obtained from borehole logs, local mines, mining equipment manufacturers, and previous mining experience should be used in the mine planning process. According to Ellison and Scovazzo (2), cost-sensitive mine planning assumes that the physical and economic conditions that will have the greatest impact on cost and coal quality can be predicted accurately enough to assist mine planners in making decisions. In the planning process, many maps, depicting such features as coal seam thickness, expected roof caving conditions, geologic lineaments, roof shale thickness, distance to the first sandstone, overburden thickness, underclay thickness, as well as a host of other factors, can be generated as overlays on each other to assist planners in selecting appropriate locations and orientations for the portal, mains, submains, and longwall panels (3).

The thrust of the present study is to examine two very important indicators of failure, namely floor heave condition and length of time that failure of roof occurred after initial coal excavation, with a host of related parameters in traditional room-and-pillar mines. Other parameters measured include: size dimensions of the actual fall itself, pillar dimensions, roof characteristics, and coal seam characteristics. Accomplishment of these tasks should provide valuable insights to the behavior mechanism of roof falls; hence, providing aids to mining engineers and geologists in the scheduling of exploration work and determining economic feasibility of certain ground control practices in the overall mine-systems design.

## Methods

### *Study Area and Parameters Studied*

Cooperation by four mining companies in five different mines, mining the Fire Clay, Pond Creek, Peach Orchard, and Broas Coal Seams of the Eastern Kentucky Coal Field, allowed the investigation and data collection of failure parameters associated with 250 roof falls. The data were empirically collected through actual mine visits and questioning responsible shift and face foremen and other personnel. Actual measurements of bolt length and entry spans were performed.

The mine locations and entry-types are located in counties of Floyd, Pike, and Martin. All the coal seams are part of the Breathitt Formation in the lower and Middle Pennsylvanian Series. It is generally accepted that the deposition of these coals and their associated lithologies took place on deltas and deltaic lobes with the source area to the northwest and sediment transportation to the east and southeast (4-6). Deposition of these deltas and lobes took place within the Pocahontas Basin, which is a smaller basin within the larger Appalachian Basin. The intervals between the four coal seams are cyclic, either a coarsening upward or fining upward sequence. This cyclic sequence is a key stratigraphic relationship that permits the use of several coal seams. Hence, for comparison purposes and geographic coverage, all the mine-roof failure data collected from the five mines and four seams were used in the analysis. Overall, as illustrated in Figure 4, the majority of falls were measured in Martin County (149 total, 60 percent), followed by Pike (86 total, 34 percent), and Floyd Counties (15 total, 6 percent).

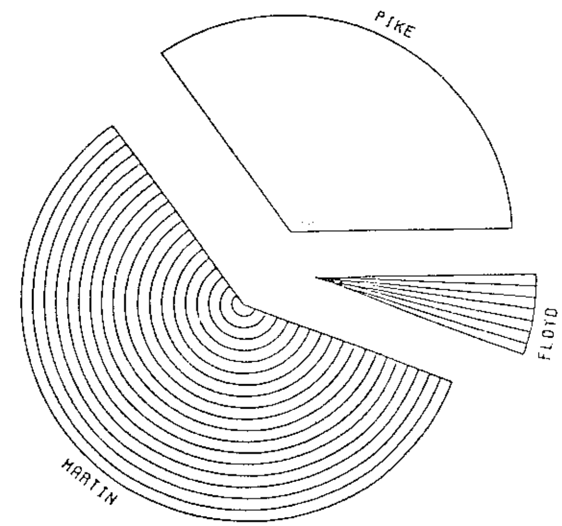


Figure 1. Distribution of mine-roof falls by county in eastern Kentucky.

The dependent parameters chosen for statistical evaluation, including floor heave condition and time failure, occurred after initial coal extraction. The associated, independent parameters also studied in conjunction with the criterion variables included the following: sloughing of coal ribs before failure, condition of mine roof before failure, presence of cracks before failure, presence of water before failure, distance from the nearest working face to failure, type of support system in place before failure (resin or mechanical-anchor bolts). length of bolts in place before failure, length of entry span adjacent to fall area, pillar dimensions, depth to coal seam, thickness of coal seam, thickness of thinnest layer in roof bed, and size dimensions of the actual fallen debris associates with the mine roof failure. Although this is certainly not a comprehensive list of failure parameters associated with roof collapse in coal mines, it does represent a list of readily available parameters that can be quickly recorded and statistically evaluated for forecasting potentially dangerous areas.

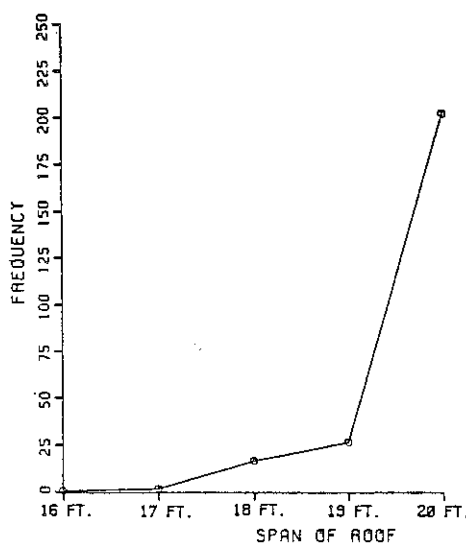


Figure 2. Length of entry span adjacent to mine-roof failure areas.

## Research Hypotheses

A number of research hypotheses were generated to test selected relationships among the parameters of sloughing, mine-roof condition, distance to the nearest working face, presence of crack, water in the roof before the fall, and type of support system in use before the fall occurred, with the criterion variables floor-heave condition and time failure which occurred after the initial coal extraction. The first general hypothesis tested all these variables together to determine if a statistically significant amount of explained variance in predicting floor-heave condition before failure could be based on the variance among the independent parameters. The specific-research hypotheses were formulated to investigate each independent parameter with floor-heave condition as the criterion. Since floor heave condition is a measure of the stress placed on the roof, via the pillars pinching into the floor, investigating the relationships associated with differential-floor movement may aid models to forecast roof instability. The same scheme was applied to testing relationship with time of failure as the criterion. If length of time that the mine-roof fall occurred can be predicted by the other observable parameters, then safety margins can be estimated after coal removal.

## Statistical Techniques

Various statistical techniques were utilized to inspect the interrelationships of these failure criteria. Since the present study deals with a combination of continuous and discrete or categorical parameters, multiple linear regression (MLR) techniques and related full- and restricted-model comparisons and hypotheses testing were employed to analyze the data.

The second statistical technique utilized was the Newman-Fry Correction for Multiple Comparisons (7), which was developed to control for post prior tests by correcting the levels of significance. Since a number of nonindependent comparisons were made in the course of the present study, the Newman-Fry correction method was used to keep the desired alpha level of 0.05 constant across a number of comparisons determined in the study.

Table 1. Descriptive statistics for selected continuous-geotechnical parameters associated with mine roof falls.

| Parameters | Mean | Range | Variance | Standard Deviation | Kurtosis | Skewness |
|---|---|---|---|---|---|---|
| [a]DEPTH (ft.) (N=250) | 512.5 | 750.0 | 36481.8 | 191.002 | -0.729 | 0.177 |
| [b]SPAN (ft.) (N=240.) | 19.7 | 4.0 | 0.4 | 0.661 | 6.769 | -2.557 |
| [c]PILWID (ft.) (N=250) | 42.9 | 20.0 | 32.8 | 3.728 | -0.553 | -0.103 |
| [d]PILLWN (ft.) (N=250) | 48.1 | 90.0 | 179.4 | 13.395 | 5.479 | 1.700 |
| [e]COAL THICK (in.) (N=250) | 68.2 | 108.0 | 634.1 | 25.182 | 1.823 | 1.511 |
| [f]ROOFLN (in.) (N=250) | 672.8 | 9969.0 | 952214.8 | 975.815 | 68.016 | 7.632 |
| [g]ROOFWID (in.) (N=250) | 244.9 | 582.0 | 4208.0 | 64.874 | 9.832 | 2.030 |

Table 1. Cont.

| Parameters | Mean | Range | Variance | Standard Deviation | Kurtosis | Skewness |
|---|---|---|---|---|---|---|
| [h]ROOFHT (in.) (N=250) | 79.0 | 468.0 | 1757.6 | 41.924 | 33.673 | 4.206 |
| [i]THINLAY (in.) (N=250) | 7.0 | 899.0 | 3387.7 | 58.204 | 225.418 | 14.771 |
| [j]TIME (weeks) (N=230) | 40.0 | 519.9 | 6142.9 | 78.376 | 13.554 | 3.475 |
| [k]DISTANCE (ft.) (N=229) | 87.9 | 101.0 | 867.4 | 29.451 | 3.460 | -2.205 |

Note: The Symbol N in the parentheses denotes total number of valid data. The actual computation of the descriptive statistics involved being a listwise deletion of the missing cases.

[a]Denotes depth to top of coal seam.
[b]Denotes span of entries associated with roof failure.
[c]Denotes coal pillar width.
[d]Denotes coal pillar length.
[e]Denotes thickness of coal seam.
[f]Denotes longest length of mine roof failure.
[g]Denotes width of mine roof failure.
[h]Denotes height of mine roof failure.
[i]Denotes thickness of thinnest, immediate-rock-layer in mine roof.
[j]Denotes time after initial coal extraction that roof failure occurred.
[k]Denotes distance from roof failure to nearest working face.

**Results and Discussion**

Table 1 presents the basic descriptive statistics for a variety of continuous data, especially concerning size and dimensional characteristics of fallen debris from failed areas, pillar characteristics, and coal seam measures. Table 2 summarizes the $R^2$ values for both full and restricted models, degrees of freedom, F-ratios, probability levels, and statistical significance, at the alpha level of 0.05 for a nondirectional test, once corrected for multiple comparisons, involved in the model comparisons and hypotheses testing process. Figure 2 graphically illustrates the length of entry span adjacent to mine-roof failure areas. Overall, the mine-roof falls occurred over 100 feet from the nearest working face, showed presence of cracks before failure of roof (61 percent), showed approximately equal occurrence of sloughing of coal ribs (43 percent) and stable ribs (49 percent), presented virtually no presence of floor heave condition before actual roof failure (88 percent), and mainly mechanical-anchor bolts of 48 inches (36 percent) or 60 inches (44 percent) in use in the hanging wall before collapse occurred. The pillar dimensions averaged 48 feet by 43 feet (mainly square pillars), the coal seam had a mean of 68 inches, depth of about 512 feet, approximately 40 weeks occurred after initial coal excavation before roof failure occurred, and the roof-fall dimensions were highly variable (averaging 67 inches long, 350 inches wide, and 80 inches in height).

Table 2. Summary of models tested, $R^2$ values for both the full and restricted models, degrees of freedom-numerator, degrees of freedom-denominator, F-ratios, probability levels, and statistical significance for each research hypothesis testing relationships among selected physical parameters associated with coal-mine roof failure.

| Independent Parameters | $R^2$ Full | $R^2$ Restr. | $df_n/df_d$ | F-Ratio | Prob. | Sign. |
|---|---|---|---|---|---|---|
| FLOOR HEAVE CONDITION BEFORE FAILURE (criterion) | | | | | | |
| SLOUGH, CONDIT, CRACKS, DISTANCE TIME, SUPPORT BEFORE,WATER | 0.08791 | 0.0 | 7/187* | 2.57470 | 0.0148 | S** |
| SLOUGH | 0.01861 | 0.0 | 1/193 | 1.65975 | 0.0572 | NS*** |
| CONDIT | 0.00004 | 0.0 | 1/193 | 0.00722 | 0.9324 | NS |

Table 2. Cont.

| Independent Parameters | $R^2$ Full | $R^2$ Restr. | $df_n/df_d$ | F-Ratio | Prob. | Sign. |
|---|---|---|---|---|---|---|
| CRACKS | 0.00588 | 0.0 | 1/193 | 1.14201 | 0.2866 | NS |
| WATER | 0.07143 | 0.0 | 1/193 | 14.84615 | 0.0002 | NS |
| DISTANCE | 0.00053 | 0.0 | 1/193 | 0.10249 | 0.7492 | NS |
| TIME | 0.00347 | 0.0 | 1/193 | 0.67276 | 0.4131 | NS |
| SUPPORT BEFORE | 0.00977 | 0.0 | 1/193 | 1.90335 | 0.1693 | NS |
| TIME FAILURE OCCURRED AFTER INITIAL COAL EXTRACTION (criterion) | | | | | | |
| FLOOR, SLOUGH, CONDIT, CRACKS, WATER, DISTANCE, SUPPORT BEFORE | 0.15328 | 0.0 | 7/187 | 4.83585 | 0.0000 | S** |
| SLOUGH | 0.05843 | 0.0 | 1/193 | 11.97592 | 0.0007 | S** |
| CONDIT | 0.00173 | 0.0 | 1/193 | 0.33302 | 0.5646 | NS |
| CRACKS | 0.00008 | 0.0 | 1/193 | 0.01625 | 0.8987 | NS |
| WATER | 0.02441 | 0.0 | 1/193 | 4.82931 | 0.0292 | NS*** |
| DISTANCE | 0.04634 | 0.0 | 1/193 | 9.37920 | 0.0025 | S** |
| SUPPORT BEFORE | 0.05372 | 0.0 | 1/193 | 10.95715 | 0.0011 | S** |

Note: An F-test was utilized to test for significant relationships among selected failure parameters. The assigned alpha level of 0.05 was considered statistically significant. However, the employment of a correction for multiple comparisons was necessary for several cases, using the Newman and Fry (1972) method. The corrected alpha level of 0.007 was used before any specific research hypothesis was considered significant. The symbols and their coding for the independent and criterion variables are defined in Table 1.

*The actual computation of the degrees of freedom, both numerator and denominator, involved a listwise deletion of the missing cases.

**Statistical significance at the 0.01 alpha-level for a two-tailed nondirectional test.

***Approaching statistical significance at the 0.05 alpha level for a two-tailed, nondirectional test.

An in-depth inspection of the hypothesis-testing results (Table 2) revealed a number of interesting relationships, but in most cases the $R^2$ values were relatively low, even when the hypotheses were found to be statistically significant. This condition may be indicative of the complexity of the interrelationships found in describing and quantifying the parameters associated with coal-mine roof failure. In general, occurrence of sloughing of the coal ribs before the mine-roof failed was slightly related to the increased presence of floor heave ($R^2$ = 0.02, p = 0.06). Increased amounts of water were also found to be statistically significant in predicting the occurrence of coalrib failure for the roof falls studied ($R^2$ = 0.07, 0 = 0.0002). In addition, several variables were found to significantly predict the time of the mine-roof fall after coal extraction. Those variables were: sloughing of coal ribs before the fall ($R^2$ = 0.06, p = 0.0007), distance of the mine-roof fall from the nearest working face ($R^2$ = 0.05, p = 0.0011). Hence, less time of the mine-roof fall occurrence after coal extraction was significantly associated with increased sloughing of coal ribs before failure of roof, less distance from the working face, and greater occurrence of mechanical-anchor bolts used for initial support before failure.

Since mechanical-anchor bolts are the most common roof support system in use in American coal mines (8, 9), coupled with small contact with the small contact area that the mechanical-anchor bolt has, as compared to full- or partial-column (resin) bolts, it would be expected that if a roof is to fail, it would more likely fail under mechanical-anchor bolts than resin bolts. Also, as found in the study, if the roof is to fail due to stress build-up after removal of coal and contains weak strata, the roof fall would occur sooner after initial coal excavation. In addition, as found in the hypotheses testing, sloughing of the ribs were associated with less time before failure of roof. Since sloughing ribs increase the total entry span of the roof, it is logical to assume that increase span would greatly weaken the roof, eventually leading to its rupture and collapse.

## Conclusion

The prediction and eventual control of mine-roof falls are, of course, one of the primary goals of the mine planner and engineering. However, the task of quantifying the magnitude of factors associated with the potential roof fall is monumental in scope. A few of these factors were statistically evaluated in relationship to presence of floor heave and time after initial coal extraction before roof failure occurred to very important parameters associated with roof falls. Several important relationships were found among floor heave condition and sloughing of coal ribs, distance to nearest working face, and type of roof-support system in place before failure. However, the $R^2$s values were found to be relatively low indicating large amounts of unexplained variances among the dependent and independent parameters. Although techniques for better and safer roof-control systems will continue to develop with increasing technology, a detailed collection and statistical analyses of this information can prove valuable aids to understanding the mechanics of mine-roof falls in American coal mines.

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# Analysis of SLAR Lineaments of the Area of the Burning Springs Anticline

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### Abstract

Analysis of lineaments mapped from new (1984) side-looking airborne radar (SLAR) images for an area near the Burning Springs anticline of northwest West Virginia confirms some of the findings of earlier studies based on various imagery forms. Several lineament sets oriented parallel and perpendicular to fold axes provide up to eight different orientations for the area. Several east-west faults mapped from subsurface information were not delineated by lineaments; however, the westward look of the imagery biases against features of that orientation. In the immediate vicinity of the Burning Springs anticlinal axis, preferred orientation peaks on rose diagrams are broader. Elsewhere, lineament patterns are more chaotic in areas of gentle dips than in areas of steep dips. Also, lineament density is about 20% greater near the anticlinal axis, due to more intense fracturing or possibly greater topographic relief, although similar greater topographic relief near the Ohio River does not show a higher lineament density. A visual impression of higher densities corresponding to steeper structural dips was noted. Rotational shifts of preferred orientation peaks were not strong or consistent, and lineament density does not appear to differ between areas east and west of the Burning Springs anticline, as has been indicated in previous studies.

### Introduction

The Burning Springs anticline (Figure 1) has been of interest to geologists since the beginnings of the West Virginia oil and gas industry. The first wells intentionally drilled for oil in the state were there. The area has been important in understanding the structural development of the Appalachians and mountain ranges in general.

In the last twenty years, there has been considerable interest in the use of photography and other imagery for the mapping of geological structures, particularly those obscure at ground level. Much current work is in the evaluation of newer forms, such as digital satellite scanning images and SLAR images. Because of industry interest, much of this work has been oriented towards oil and gas exploration in areas such as the Burning Springs anticline.

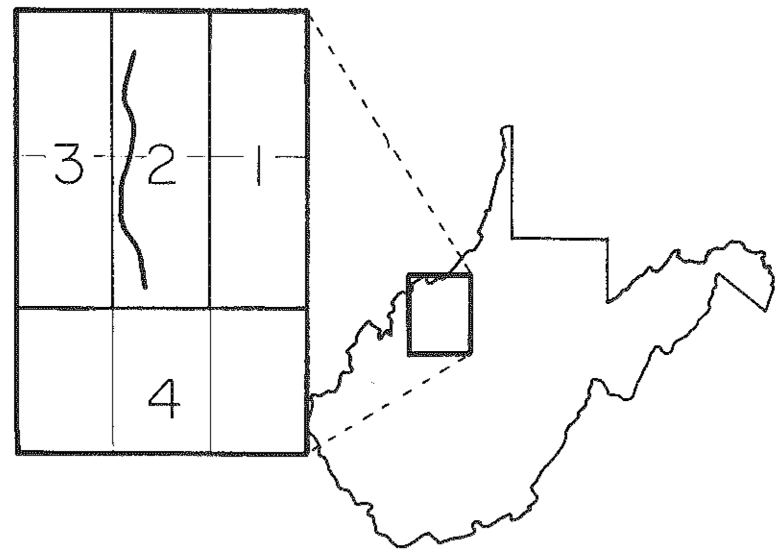


Figure 1. Index map showing study area. Numbers on inset indicate area of different structural characteristics referred to in text.

An early study of geologic structure using SLAR was done by Wing, Overbey, and Dellwig (1970) on portions of the Burning Springs area. They used an early SLAR whose areal coverage was limited. Recently, the U. S. Geological Survey (USGS) has provided more extensive SLAR coverage, including most of the Appalachians, which is available as mosaics laid on the $1^{o}X2^{o}$, 1:250,000-scale quadrangle maps.

In an earlier Landsat-based study (Werner, 1980a, 1980b), a variety of questions regarding photolineaments and fractures measured on rock outcrops were formulated and evaluated. The present study is an addendum to that earlier study. In the Landsat-based study, comparisons were made between two areas; one east and one west of the anticlinal axis. Photolineament density appeared to be higher in the eastern area than in the west, but it was also noted that this might be due to image variations rather than real variations on the ground. This question has been addressed again in this study, and the distribution of photolineaments was further investigated, this time by using smaller areas (nine in all, as shown in Figure 1) so that differences between areas with lesser variation in geologic structure could be determined.

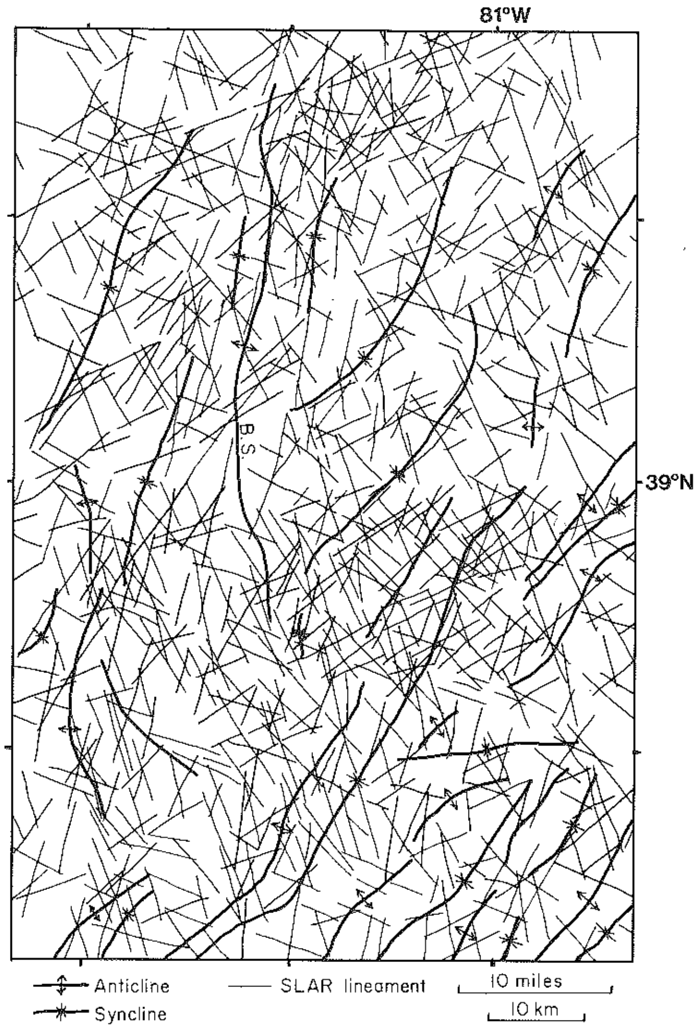


Figure 2. Lineaments mapped from SLAR images, and fold axes after Cardwell, Irwin, and Woodward (1968).

## Methods and Materials

The radar images consist of north-south flight strips, with a west look direction, about twelve miles apart. The mosaics produced from these flight strips by the USGS were used to map lineaments visually. No mechanical, digital, or optical enhancements were applied. A transparent overlay was affixed to the paper copy of the mosaic and lineaments mapped on the overlay. This map (Figure 2) was then subdivided into nine equal parts and each section separately digitized with a computer-based system. The resulting data were then processed into rose diagrams (Figures 3 and 4) and cumulative orientation distribution diagrams (Figure 5).

In order to plot rose diagrams, it is necessary to choose two parameters - grouping interval and averaging interval. Actual orientation values are grouped into convenient intervals, depending on number of data and precision of the actual measurements. In the illustrations here, this value was three degrees. The averaging interval controls the number of points, three in this paper, used for the running average, thus each point plotted on the rose diagrams contains data from a nine-degree segment of the circle. For a discussion of how these variables affect rose plots, see Werner (1971b).

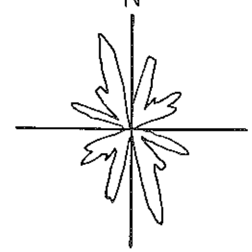


Figure 3. Composite rose diagram of SLAR lineament orientations for entire study area.

Whereas rose diagrams give a visual indication of directions of preferred orientation, cumulative orientation distribution diagrams indicate both the degree of preferred orientation and, more generally, the preferred sector. If the orientation values are distributed at random, then one would expect the cumulative orientation distribution diagram to be a diagonal line (Figure 5), and the deviation that is a measure of the degree of preferred orientation. In the Kuiper (1960) test for preferred orientation (a modification of the Kolmogorov-Smirnov test) the greatest single difference between two data sets is used to determine whether or not the two are significantly different; the cumulative orientation distribution diagram is a graphical device based on the same principle. In this paper, average, rather than maximum, deviation from a random distribution was used as an indicator of the "peakiness" of the distribution, partly to avoid the variation induced by the arbitrary selection of the starting point for the accumulation. A large value for average deviation usually indicates that a few large, sharp peaks exist in the distribution, whereas a small value indicates many small peaks or very broad peaks. The largest average deviation possible is 0.25. These values were used only for relative comparisons; no test for statistical significance was applied.

## Results and Discussion

Figure 2 shows approximately 3000 miles (5000 km) total length of mapped lineaments. In general, these are distributed throughout the area (see Table 1), although some areas have more than others. The highest density is in areas near the axis of the Burning Springs anticline which have high-dip strata. Here, the density is approximately 20% above average. Higher lineament densities are usually associated with higher topographic relief, because most lineaments represent linear topographic features such as streams and ridgelines, and these are more prominent where topographic relief is high. However, topographic relief throughout the study area varies only slightly, so the variation in lineament density most likely reflects differences in rock fractures. Considering the scale involved, the difference in lineament density is more likely to be due to variation in permeability of fracture *zones* rather than a greater frequency of individual fractures, even though the latter probably also occurs.

A comparison between the lineament map in Figure 2 and that of the earlier paper (Werner 1980b) shows many differences which are not unexpected given the varied ways the maps were prepared. The earlier map was produced from Landsat images and showed only about 560 miles (900 km) total length of lineaments. This is due to lower resolution of the Landsat image, which tends to obliterate or blur many of the individual lineaments which are visible on the SLAR images. For the same reason, the average lineament is about three times as long on the Landsat-based map as on the SLAR-based map.

There have been a number of studies regarding the reproducibility of lineament maps, particularly ones for the same area done by different interpreters and/or from different images. Most (e.g., Pratt et al., 1986) indicate that there is usually very little coincidence of



the lineaments shown on any pair of maps. Because lineament mapping is largely subjective, different interpreters are likely to choose different features. However, even when the interpreter remains the same, difference in images will produce equally great variation (Werner, 1977). It is no surprise that there is little coincidence between the Landsat and SLAR maps. In most cases, coincidence is shown where one Landsat lineament occupies the same space as a series of aligned or en echelon SLAR lineaments, as is normal when images of different scales or resolutions are used.

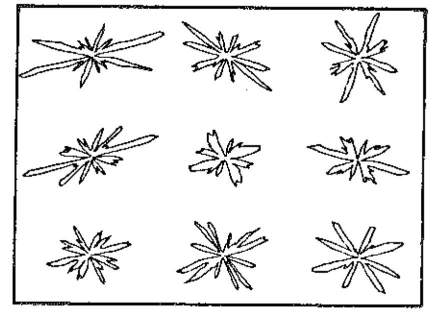

Figure 4. Rose diagrams of SLAR lineament orientation for each ninth of the study area.

The apparent difference between east and west portions of the Landsat-based map of the earlier paper (Werner, 1980b) is due more to image variations than real differences; there is no significant difference in corresponding areas on the SLAR-based map. The difference on the Landsat-based map is an artifact caused by a combination of look direction and sun angle which creates stronger topographic shadowing on the east half of those images. The SLAR image allows for a more complete and accurate map because of its higher resolution and more consistent image characteristics.

Inspection of the map combining the photolineaments and structural folds of the area (Figure 2) shows several relationships. Very few lineaments are coincident with fold axes, probably for the same reasons as those which cause differences when images of different resolution are used. Conceptually, field mapping is the same as using low resolution images - data points are limited and often widely spaced. Hence, maps showing structural axes often show averaged positions. In fact, more recent, higher resolution studies of the study area (e.g., Filer, 1985) indicate that bends in the fold axes may be offsets caused by strike-slip faulting. Thus photolineaments may give a more detailed picture of fold axes than the conventional geologic maps (e.g., Cardwell, Erwin, and Woodward, 1968). Most trends exhibited by fold axis segments are also strongly exhibited by photolineaments of the area. Furthermore, where the mapped axes terminate on the published map, the photolineament map often indicates an extension, probably of less structural relief, of the same feature (throughout the study area, but especially in the northeast and east-central ninths of Figure 2). On the other hand, the east-west faults shown by Filer (1985) are not represented by lineaments, probably because their orientation is deemphasized by the SLAR look direction. As noted by Wing, Overbey and Dellwig (1970, p. 3438), "lineaments which are roughly normal to the look direction will generally be better expressed on SLAR imagery than those lineaments parallel to the look direction" because the method depends on the reflected signal strength which is dependent on the angle of the reflecting surface in the radar beam.

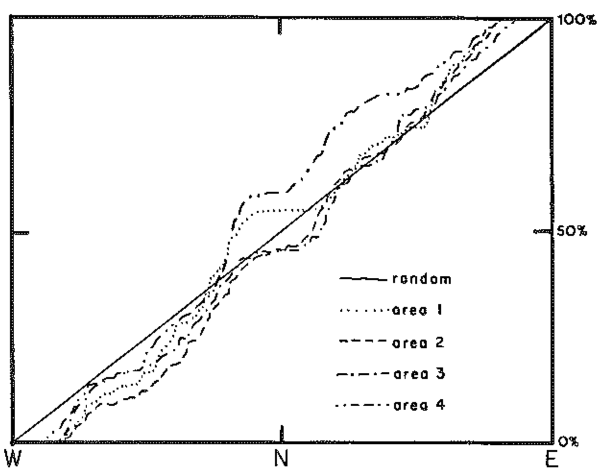


Figure 5. Cumulative orientation diagram of SLAR lineaments. "Random" refers to hypothetical reference distribution with no preferred orientation. Numbered areas refer to structurally determined areas shown in Figure 1.

When the study area is divided into portions which might reasonably be structurally related, that is areas: 1) east of the most deformed portion of the anticline, 2) on the anticline where relatively high bedding dips are found, 3) west of the most deformed portion of the anticline, and 4) south of where the anticlinal axis has been mapped (see Figure 1), one might expect to see some differences in the nature or orientation of fractures and lineaments.

Table 1. Values of cumulative lineament length and deviation from random orientation for each ninth of the study area.

| LINEAMENT LENGTH | | | DEVIATION FROM RANDOM | | |
|---|---|---|---|---|---|
| 1.61 | 2.13 | 1.53 | 0.030 | 0.056 | 0.051 |
| 1.82 | 2.16 | 1.76 | 0.063 | 0.050 | 0.044 |
| 1.59 | 1.94 | 1.43 | 0.073 | 0.081 | 0.049 |

Figure 5 shows the cumulative orientation distribution diagrams for each of the structurally related areas. The diagonal reference line represents the random distribution, and deviations from this line show the relative amount of preferred orientation. The orientation of the Burning Springs anticline is anomalous for the Central Appalachians, so its influence might be expected to blur the preferred orientations of fractures and other small structures of the area. Inspection of the lineament data shows this to be true. The areas with the smallest deviations (area 1 with a value of 0.046 and area 3 with a value of 0.041) probably have about equal contributions from normal Central Appalachian trends and Burning Springs anticline trends, as also indicated by the large number of prominent orientation peaks on the rose diagrams of Figure 4. On the Burning Springs anticline (area 3 with a deviation value of 0.052), broader orientation peaks appear, probably due to localized small but random rotations of blocks or stresses; either would tend to produce minor changes in fracture orientation. Somewhat more puzzling is the area south of the anticline (area 4 with a deviation value of 0.069) which shows the greatest degree of preferred orientation. This may be because the stresses which were released in faulting and folding of the anticline to the north were released here primarily in fracture development which produced no rotation. The principal orientations here are related to the Burning Springs anticline rather than the Central Appalachians.

The rose diagrams of lineament orientations for the area show several prominent preferred orientation peaks. On the summary plot

(Figure 3) for the whole study area, four prominent peaks - N70$^{O}$W, N18$^{O}$W, N15$^{O}$E, and N50$^{O}$E - and two lesser peaks - N40$^{O}$W and N65$^{O}$E - appear. There is a notable absence of north-south and east-west orientations. Rose diagrams based on the subdivided areas (ninths) of the study area (Figure 4) show similar preferred orientations. These same directions are commonly encountered in similar studies in the Appalachian area; however, the general regional trend corresponding to Central Appalachian structures, at N40$^{O}$E, is not at all well represented in this area although it does appear in the west-central ninth and as a minor peak in the northwest, north-central, and southwest ninths. The N18$^{O}$W and the minor peak at N65$^{O}$E represent typical Southern Appalachian structural orientations, and are also generally found in fractures, lineaments, and segments of fold axes of the Central Appalachians.

Some earlier studies (Wing, Overbey, and Dellwig, 1970; Werner, 1979a) have reported rotational shifts of preferred lineament orientation peaks. If such exist in this study area, it is not readily apparent from the data summarized by the rose diagrams of Figure 4. As mentioned earlier, it appears that localized rotation occurs, but individual rotated blocks are too small to show at the scale of this analysis.

The fact that east-west lineaments are missing is probably due to image factors, because structural elements such as cross-strike faults (Filer, 1985) and some rock fractures (Werner, 1980b) are known at this orientation. The westward look direction of the radar would tend to deemphasize them. This factor, however, does not explain why no lineaments were seen in the north-south direction, which is the direction most emphasized. Rock fractures are common at this orientation (Werner, 1980b); however, if these are evenly distributed, there would be no fracture *zones* to appear as lineaments in the images.

It is not easy to make a comparison between the present study and that of Wing, Overbey, and Dellwig (1970) because of the differences in mapping and data processing procedures. As noted above, positions of lineaments on different maps often differ; however, this is usually not the case for orientation distributions. Differences occur because of lighting angles or scanner look directions, but such differences are usually not statistically significant. In general, the lineament orientation distributions for corresponding portions of the respective study area are similar. A number of east-west lineaments are shown by Wing, Overbey, and Dellwig (1970), a direction absent in the present study. This is to be expected because the look direction of their imagery was to the north, and most other differences between their results and present study may be assigned to the same cause.



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# Mathematics Section

## A CHARACTERIZATION OF COMPACTNESS

Sam B. Nadler, Jr.

A cover $\mathcal{C}$ of a space X is said to be minimal, or irreducible [1, p.160], rovided that no proper subset of $\mathcal{C}$ covers X. It is well known that point nite covers have minimal subcovers (e.g., see 1.1 of [1, p.160]). This result as applications in the theory of paracompact and metacompact spaces. For xample, it is used to show that compactness and countable compactness are quivalent in metacompact spaces (3.3 of [1, p.229]). We will obtain a companion esult in THEOREM 3.

Our main result is the following theorem:

**HEOREM 1:** A topological space (X,T) is compact if and only if

#) every open cover of X has a minimal subcover.

It is convenient to have the following lemma:

**EMMA 1:** Let X be a nonempty set and let $\mathcal{N}$ be a nest of subsets of X covering X. If $X \notin \mathcal{N}$, then $\mathcal{N}$ does not have a minimal subcover.

PROOF OF LEMMA 1: Let $\mathcal{S}$ be any subcover of $\mathcal{N}$. Since $X \neq \emptyset$, $\mathcal{S} \neq \emptyset$. Hence, there exists $A \in \mathcal{S}$. Since $X \notin \mathcal{N}$, $A \neq X$. Thus, since $\mathcal{S}$ is a nest covering X, there exists $B \in \mathcal{S}$ such that $A \subset B \neq A$. Clearly, then $\mathcal{S} - \{A\}$ is a proper subcover of $\mathcal{S}$. Therefore, we have proved that no subcover of $\mathcal{N}$ is minimal.

PROOF OF THEOREM 1: Clearly, compactness implies (#) since finite subcovers have minimal subcovers. Conversely, assume that (#) holds and $X \neq \emptyset$. For any set S, let $|S|$ denote the cardinality of S. Let $\mathcal{U}$ be an open cover of X. By (#) $\mathcal{U}$ has a minimal subcover $\mathcal{M}$. We show that $\mathcal{M}$ is finite. Suppose that $\mathcal{M}$ is infinite. Let (see Appendix in [2]) $\Lambda$ be a well-ordered set such that $|\Lambda| = |\mathcal{M}|$ and

(i) for each $\lambda \in \Lambda$, $|\{\alpha \in \Lambda: \alpha < \lambda\}| < |\Lambda|$ $(= |\mathcal{M}|)$.

Note that since $|\Lambda|$ is infinite, it follows immediately using (i) that $\Lambda$ has no largest element. Let $f$ be a function from $\Lambda$ onto $\mathcal{M}$. For each $\lambda \in \Lambda$, let $V_\lambda = \bigcup\{f(\alpha): \alpha < \lambda\}$. Let $\mathcal{V} = \{V_\lambda : \lambda \in \Lambda\}$. Since $\Lambda$ has no largest element and $f(\Lambda) = \mathcal{M}$, it follows easily that $\mathcal{V}$ is an open cover of X. If $X \in \mathcal{V}$, say $X = V_\lambda$ then $\{f(\alpha): \alpha < \lambda\}$ is a subset of $\mathcal{M}$ covering X which, by (i), has cardinality less than $|\mathcal{M}|$ - a contradiction to the minimality of $\mathcal{M}$. Hence, $X \notin \mathcal{V}$. Thus, since $\mathcal{V}$ is a nest covering X and $X \neq \emptyset$, we have by LEMMA 1 that $\mathcal{V}$ does not have a minimal subcover. This contradicts (#). Therefore, $\mathcal{M}$ is finite and we have proved THEOREM 1.

Recall that a space is said to be <u>countably compact</u> provided that every countable open cover has a finite subcover [2, p.162]. The proof of the following result is similar to the proof of Theorem 1 (with $\Lambda = \{1, 2, \ldots\}$).

**THEOREM 2:** A topological space is countably compact if and only if every countable open cover of it has a minimal subcover.

Let us say that a space (X,T) has property ($\beta$) provided that there is a base $\mathcal{B}$ for T such that every cover of X by members of $\mathcal{B}$ has a minimal subcover. Property ($\beta$) is weaker than condition (#) in THEOREM 1 - in fact, every discrete space has property ($\beta$). In view of THEOREM 3 below and 3.3 and 3.4 in [1, pp. 229-230], it would be of interest to determine various classes of spaces which have property ($\beta$).

The following lemma is known for $T_1$-spaces [2, p.162; E].

**LEMMA 2:** If (X,T) is countably compact, then every infinite open cover of X has a proper subcover.

PROOF OF LEMMA 2: Let $\mathcal{U}$ be an infinite open cover of X. Let $\mathcal{V}$ be a countably infinite subcollection of $\mathcal{U}$. Let $W = \bigcup(\mathcal{U} - \mathcal{V})$. Then, $\mathcal{V} \cup \{W\}$ is a countable open cover of X. Thus, since (X,T) is countably compact, $\mathcal{V} \cup \{W\}$ has a finite subcover $\mathcal{F}$. It follows easily that $(\mathcal{F} \cap \mathcal{V}) \cup (\mathcal{U} - \mathcal{V})$ is a proper subcover of $\mathcal{U}$.

**THEOREM 3:** In topological spaces having property (β), compactness and countable compactness are equivalent.

PROOF OF THEOREM 3: Let (X,T) be a countably compact space having property (
Since (X,T) has property (β), there is a base $\mathcal{B}$ for T such that all covers o
X by members of $\mathcal{B}$ have minimal subcovers. By LEMMA 2, such minimal sub
covers must be finite. Therefore, since $\mathcal{B}$ is a base for T, it follows that (X,T
is compact.

In comparing our THEOREM 3 with 3.3 of [1, p.229], we note that property
does not imply metacompactness. For example, let X = {1, 2, 3, . . . } and let T
{A ⊂ X: 1 ∈ A or A = ∅}. By letting B = {{1,n}: n = 1, 2, . . . }, we see that (X,T) h
property (β). However, (X,T) is not even countably metacompact.

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# Physics Section

## Pressure Attenuation in Solids: A Computer Model


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### Abstract

The peak pressure in a material produced by a shock wave decreases as the wave passes through the object. The rate of decrease depends on the size, shape, and molecular structure of the object. Pressure is a key consideration when evaluating insensitive high explosive (IHE) candidate materials. Current state-of-the-art computer codes are extremely complex and are difficult, time consuming affairs to apply. A simpler, more direct approach is described in this report. It is capable of giving peak shock wave pressure at interfaces as well as pressure attenuation as a function of distance in selected materials. Numerical approximation techniques employed are the least squares polynomial fit and Newton's method of iterative solutions for polynomial equations. The results obtained, although less accurate than those of the more complex codes, are far easier to obtain and are sufficiently accurate to be useful in choosing experimental parameters in IHE evaluative testing.


### Introduction

Insensitive high explosives (IHEs) have long been an area of major interest in the armed services and the defense community. Because of the tremendous energy releases associated with even conventional explosives, the safe handling, storage, and transportation of high explosives is literally a matter of life and death to those involved in these processes. IHEs are those whose behavior is such that they have passed certain cookoff, impact, and sympathetic detonation tests. Tests which in essence try to ensure that IHEs do not detonate by accident or under enemy attack, but at the same time are reliable and effective in times of military action (1).

The problems associated with the understanding and prediction of detonation characteristics are extremely complex. They involve several fields of both chemistry and physics and often several states of matter within those fields (2). As such, they have not lent themselves to a simple tractable solution (3). The most successful approach is one that has developed over the last thirty years and has increasingly involved the use of rather sophisticated computer analysis. The software associated with this analysis started with a "sin" code and led to several spin-offs. All of these are finite difference approximations. Differences between burning and detonation, heterogeneous and homogeneous materials, and various geometries can all be approximated by addition to the original program, such as Forest Fire and Sharp-Shock Burn (4). This, of course, adds to the complexity of the analysis.

Currently, the situation is such that in the ordinary day-to-day operations of the laboratory, these models are far too complex to be of any use. Typically, they will take an expert in the field several months to enter the appropriate initial and boundary conditions, run the program, and then check to see if the results make sense. Hence, these computer codes are really viable only at the large research facilities such as Los Alamos and Sandia.

At the smaller laboratories, there is a need for a more simple approach to obtain reasonably accurate predictions for explosive parameters as new IHEs are developed and tested on a daily rather than a yearly basis. The major objective of this research was to develop one such model and because of its generality it may be of interest to those outside the defense community.

## The Analysis

It was decided that the most reasonable procedure would permit a shock wave to be transmitted between two different materials and then look at pressure attenuation of that shock wave in the second material as a function of the thickness of this second substance. Such a strategy would then, with some minor modifications, allow analysis of shock transmission and pressure attenuation in several materials in contact with one another.



The starting point for the model developed is the Hugoniot curve for the material being considered. This curve is the set of all possible shock states in the material. There are several such curves for each material just as there are several interrelated parameters that can describe a particular state. One can experimentally determine the shock wave speed in the material with a standard streak photograph, pressure pins, or some similar technique. If the density is known, one can then obtain the corresponding pressure and particle velocity (2).

Table 1. Coefficients of equation. Non-explosive materials.

| Material | a | b | c |
|---|---|---|---|
| Aluminum | -0.99 | 15.96 | 3.21 |
| Baryllium | 0.23 | 14.45 | 2.17 |
| Brass | 0.01 | 31.74 | 11.91 |
| Calcium | -0.12 | 5.79 | 1.44 |
| Cesium | -1.58 | 2.57 | 2.20 |
| Copper | 0.17 | 34.58 | 13.43 |
| Lithium | 0.25 | 2.21 | 0.65 |
| Magnesium | 0.46 | 7.34 | 2.31 |
| PMMA | -0.57 | 4.06 | 1.46 |
| Silver | 2.46 | 29.33 | 18.10 |
| Sodium-Chloride | 0.28 | 7.03 | 2.05 |
| Titanium | -0.16 | 23.17 | 4.24 |
| Tungsten | -2.04 | 81.99 | 21.31 |
| Water | -1.14 | 3.32 | 1.17 |
| Zinc | 1.38 | 19.44 | 11.58 |

In the current research, material density, $p_o$ and shock wave speed, Us were assumed. Then, from the relationship in equation (1)

$$P = p_o U s U_p \qquad (1)$$

one can find the slope of the straight line extending from the origin to the Hugoniot Curve of Pressure, P, vs particle speed, $U_p$, for the material in question. In this case, it is the material through which the shock wave initially travels. The analytical form for the Hugoniot curve was obtained from a least squares curve fitting analysis for experimental data in Marsh (5). In all cases, it was found that the best fit for pressure versus particle speed was quadratic and of the general form given by equation (2)

$$P = a + bU_p + cU_p^2 \qquad (2)$$

where each material will have its own unique a, b, and c values. The results for the other non-explosive materials are presented in Table 1. Table 2 presents equivalent results for explosive materials indicating the general nature of the approximation. The units associated with these quantities are density ($gm/cm^3$), speeds (km/s), and pressure (GPa) unless otherwise stated.

Table 2. Coefficients of equation (2). Selected explosives.

| Material | a | b | c |
|---|---|---|---|
| Baratol | -0.03 | 7.52 | 2.31 |
| Composition B | +0.05 | 4.71 | 4.11 |
| HMX (pressed) | -0.84 | 8.06 | 1.94 |
| PBX 9404-03 | +0.29 | 3.60 | 4.38 |
| PETN (pressed) | +0.13 | 2.39 | 6.98 |
| PETN (crystal) | -0.09 | 5.12 | 3.01 |
| RDX (20% Al) | -0.38 | 6.77 | 0.88 |
| TATB (pure) | -0.01 | 3.64 | 4.85 |
| TNT (cast) | -0.13 | 4.84 | 2.31 |

The point of intersection of the straight line of equation (1) and the Hugoniot curve of equation (2) represents the incident pressure at the boundary between two materials. At this point, the Hugoniot of material one must be "flipped" (rotated 180 degrees around a vertical axis passing through this point). Then the point of intersection of this new Hugoniot curve for material one with the corresponding curve for material two will give the pressure in the second material, the one the shock wave enters. Secondary conditions require that transmitted pressure be equal to the reflected pressure in the first material and hence require this "flipping" process.

The flipped curve for material one is given by equation (3)

$$P = (a + 2bU_p^* + 4cU_p^{*2}) - (b + 4cUp^*)U_p + cU_p^2 \qquad (3)$$

where $U_p^*$ represents the particle velocity at the intersection of equations (1) and (2).

The second material can be represented by equation (2) with appropriate values for a, b, and c as given by equation (4) and Table 1 or Table 2.

$$P = a_2 + b2U_p + c2Up2 \qquad (4)$$

When equations (2) and (4) are solved simultaneously the value for P will be the pressure in material two as the shock wave enters. A straightforward but algebraically unpleasant process will yield two answers. One will typically make no physical sense and can be eliminated.

The second part of this research was to investigate the attenuation of the pressure once the shock wave is in the second material. Initially it was thought that a simple inverse polynomial function of distance would describe the results. This is not the case and it is now believed that the function itself may be a function of attenuation distance. For the accuracy needed it was found that for PMMA, the best smooth curve fit corresponded to a fourth order least squares fit of the form

$$P = A + Br + Cr^2 + Dr^3 + Er^4 \qquad (5)$$

where r is the distance the shock wave has traveled into the PMMA in millimeters. Table 3 gives the values of the coefficients of equation (5) for PMMA, when pressure is expressed in kbar.

Table 3. Coefficients of equation 5.

| PMMA | 5 m < r < 100 m |
|---|---|
| A | 13.5 |
| B | -0.492 |
| C | 7.86E-3 |
| D | -6.23E-5 |
| E | 1.98E-7 |

These results can then be used to approximate the shock wave pressure loss for a particular thickness of attenuator material. Newton's Iterative Method of solving a polynomial is used to obtain a first estimate for this loss with a final estimate obtained by choosing increasingly smaller intervals around this estimate. Unfortunately experimental data for pressure attenuation is not easily found in the literature, if indeed it exists, so that equation (5) was only evaluated for PMMA (6).

Both equations (2) and (5) can be generalized to any number of materials by evaluating the coefficients. The data for equation (2) is readily available, that for equation (5) is not. There are some limitations on the generality of the results obtained. The major one pertains to the fact that the PMMA results for equation (5) are for samples two inches in diameter. It would seem reasonable to expect different coefficients for samples of different diameter.

This particular analysis although rather limited in scope offers the opportunity to quickly and accurately approximate peak pressure values in different materials. The program can be run on any common personal or scientific computer and gives immediate results. Although clearly not of the accuracy of the complex computer codes using finite difference methods, it is far easier to use and its accuracy is good enough for choosing masses and geometries that are useful in testing new explosives, their effects, and their suitability as IHEs.



## Recommendation

There are a number of directions that one might pursue the research just described. Probably the most apparent is the acquisition of pressure attenuation data for materials other than PMMA. In addition to allowing more applications of the predictive model, we could also use it to do multiple reflections. That is, the model could then apply to a pressure wave that attenuated in several materials and passed through more than one interface.

The data that is available for pressure attenuation in PMMA applies to two-inch thick cylinders. Similar data should be obtained for cylinders of different thickness. Since pressure attenuation is a process involving both axial and side affects, the diameter of the cylinder should significantly affect pressure changes.

With different diameter cylinders of different materials, the time required for peak pressures to reach certain points in the cylinders could be measured and would provide insight into the relationship between side reflections and pressure waves.

In conclusion, let me restate that the computer model developed was at no time meant to replace the more sophisticated, more accurate, and more detailed computer codes that now exist. Instead, it is intended as one that is easier to use and, hence, can be used by scientists and technicians in related fields who might not have the time or expertise to use the more complex programs.

The computer program provides appropriate data, pressure values, both forward and backward in space, and gives them quickly. Indications and early testing results predict an agreement of better than 95% between experimental results and the model. It is this data that is useful in the design and testing of IHEs. And, it is the case with which this data will be available that will make it a useful research tool.

## Acknowledgements

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I would like to thank Mr. David Wagnon, Chief of the Dynamics Laboratory at Eglin Air Force Base, for his suggestions and guidance. They were always constructive and informative.

## Glossary

Because of the nature of any scientific research much of the language used may not be terribly familiar to someone outside the narrow scientific speciality. In order to partially alleviate this problem a brief glossary is included.

Finite Difference Method - A method for solving partial differential equations by assuming boundary or initial conditions and advancing them in small steps in time and position to achieve solutions at other locations and times.

Forest Fire - An addition onto the finite difference SIN code that takes into account the effect of a burning explosive shock front and incorporates decomposition rates for the explosive as a function of experimental parameters.

Hugoniot - The curve of all possible states of an explosive. Typically this is presented as a graph or an equation relating two variables (e. g., P vs Up, P vs Us, or P vs V).

PMMA - Polymethylmethacrylate, Plexiglass.

Sharp Shock - An addition onto the finite difference SIN code that incorporates the detonation energy by assuming after reaching a certain compression a particular small cell or section of the explosive is detonated. The arrival of the shock wave, compression, causes the cell to burn or detonate.

SIN - The first accurate finite difference solution to the partial differential equations describing the progression of a shock wave through an explosive material. It ignores detailed description of burn and detonation characteristics.

Particle Velocity, Up - The ordinary particle speed found in introductory physics. The speed at which the particles in the material are moving.

Shock Velocity, Us - The speed with which the explosive shock wave moves through the material in question.



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# Psychology Education Section

## Ideas for Classroom Instruction and Research on the Arab World: a Tunisian Case Study

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### Abstract

A Joseph J. Malone fellowship administered by the National Council on US-Arab Relations provided a month of field experience in Tunisia. As a result of that experience the author presents a series of ideas for teaching and research on the Arab world in three areas beyond the political realm. These areas are the diffusion of AIDS, the tourist industry, and the desertification process. This writer, along with the personnel of resource centers for Arab world study materials, supports the current emphasis on the internationalization of high school and college curricula in West Virginia.

### Introduction and Purpose

Today's news from the Arab world is predominantly of a political nature. Authors of literature in geography on the Arab World, however, have traditionally reflected a wide array of research topics beyond the theme of geo-politics. Examples of this diverse tradition range from studies of Arab images to studies of Arab city planning programs (Costa and Noble 1986, Yapa and Mayfield 1976, Morsy 1986). This paper is in keeping with that tradition. Its purpose is to explore areas for research and teaching beyond the political realm. A Joseph J. Malone Fellowship, July 1987, provided a month of travel and contact with educators and government officials in Tunisia. By focusing on their concerns in the north African country of Tunisia three areas of potential interest beyond the political realm were noted. These areas are agents for the diffusion of AIDS, the tourist industry and the desertification process. In several instances these topics can be generalized to other parts of the Arab world and beyond.



### Methodology

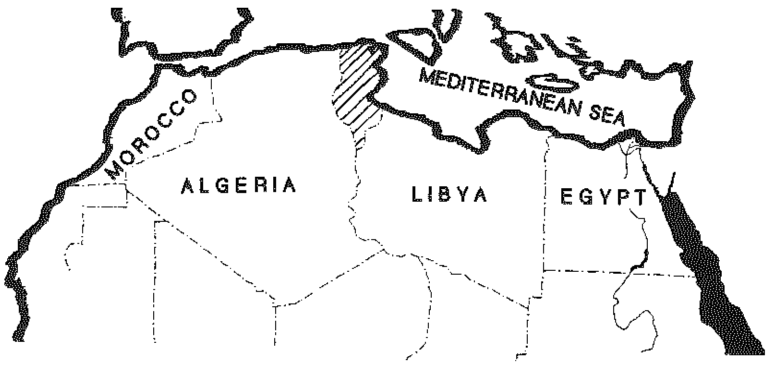
The basis for this paper is field work undertaken in the summer of 1987. Meetings with the Tunisian Ambassador to the United States, the American Ambassador to Tunisia, the President of the Tunisian Development Bank, Tunisian educators and representatives of the Tunisian Tourist Ministry were arranged by the National Council on US-Arab Relations. There was also the opportunity to meet with American British and Tunisian scholars working in the country at that time. Citations based on these contacts will be referred to as "Fieldwork". Fieldwork was put in context through archival research.

### Background to Tunisia

Tunisia is located in North Africa (Fig. 1). It has a population of seven million and is approximately one half the size of California (Geographic Yearbook 1985, Area Studies Handbook 1979). It is in a crossroad position on the Mediterranean Sea as measured by the historical landscape which runs the gamut from Phoenician to Maltese. Today, one might expect to see European tourists, international students, and foreign workers in and around the major cities. French is a common second language due to Tunisia having been a French colony.

Physically, Tunisia has a true Mediterranean climate in the north and on the east coast. The Dorsales mountains (Atlas range) provide rain shadow effect, separating the Mediterranean coastal area from the steppe and desert areas of the interior south. The Majardah river, running east from Algeria, is the only perennial river in the country. Precipitation, as might be expected, decreases from north to south.

This brief background will aid the reader in understanding the sections that follow on the diffusion of AIDS, the tourist industry, and the process of desertification.




Tunisia (striped) is located on the Mediterranean Sea between Algeria and Libya.

0 500 1000KM
Source: Golany, 1988.

Figure 1.

## The Diffusion of AIDS

There were approximately 5-7 deaths due to AIDS in 1987. The cause of death, however, was listed as the direct cause, such as pneumonia or cancer. There also exists a strong denial among Tunisian citizens that AIDS or SIDA (the French Acronym for AIDS) will be a problem in the future for them (Fieldwork 1987). In Tunisia, AIDS is viewed as a decadent western disease confined primarily to the homosexual community and to countries that condone prostitution, neither of which is acknowledged as existing in Tunisia. However, a low priced red light district in the Medina in Tunis and higher priced call girls at the more expensive hotels can be found (Fieldwork 1987). Moreover, homosexual behavior can be observed in a cafe district that caters to local Tuninisans or on the main boulevards where European men may be observed cruising for homosexual contacts (Fieldwork 1987). Beyond these agents of the diffusion of AIDS can be found male migrant workers returning regularly from Europe and tourist contacts between Tunisian and non-Tunisian made along the more sophisticated beach areas.

There is an evergrowing volume of printed material on AIDS that will provide the necessary background for social studies students. (Worldwatch 1988, US Department of Health and Human Services 1988, WHO publications 1987, 1988). In the classroom the agents of diffusion can be studied in terms of classical diffusion theory, i.e. relocation, hierarchical and contagious *vs* permeable and absorbing barriers or independent invention (Jordan and Rowntree 1986). For example, Tunisia is situated between two natural barriers, the Mediterranean sea and the Sahara desert. Since AIDS did not originate in Tunisia (independent invention can be ruled out) questions of how it arrived and will spread among the population can be modeled in terms of "jumping over the barriers" (relocation diffusion), initial carriers (hierarchical diffusion), and generalized spread (contagious diffusion). Further classroom discussion can be generated by proposing barriers to the disease that might slow it down, (permeable barriers) or stop it entirely (absorbing barriers). Students can be made aware that the same processes that account for the spread of AIDS in Tunisia will provide insight into the worldwide problem posed by the disease.

Ideas for research include recognition of the more important of the diffusion areas. Should cities, towns or resort areas receive the bulk of the resources in the fight against AIDS? Research is needed in identifying the population group most likely to have carriers. For example, would the most important carriers be migrant workers, tourists, or international students? Moreover, how much emphasis should be placed on working with the governments of potential carriers?

## The Tourist Industry

Tourism is one of the top three industries of Tunisia (UN Statistical Yearbook 1985). With the aid of Professor Marilyn Emplaincourt, University of Alabama, tourist information supplied by the *Republicque Tunisenne Office National Du Tourisme Tunisian* has been translated from French to English.

The leading tourist source area for Tunisia is France followed by West Germany, Austria, England, Italy, the combined Scandinavian countries and other countries of the Magreb (Le Tourisme Tunisien en Chiffres 1985). What is of interest is that the president of the development bank has prohibited a general tourist advertising campaign in North America (Fieldwork 1987). His reasoning is that North Americans would not be ready, en masse, for the current quality of service available. For example, the national tourist reservation board will, due to overbooking, transfer visitors from one resort to another in a somewhat arbitrary fashion. Their rationale is that one beach is the same as another and that what is most important is satisfying the tourist's desire for the beach atmosphere. For the foreign tourist, however, the beach at Hammamet is clean and sophisticated in its outlook toward topless sunbathing. To be transferred to the industrialized city of Gabes is to be faced with polluted beaches and more provincial attitudes toward behavior. On a personal scale, the food tends to be starchy. Turkish style toilets are sometimes the rule. Service is generally good. (Fieldwork 1987). To travel from Canada or the United States and experience the worst aspects of Tunisia would not further the goals of the Tunisian tourist industry at this time. To help compensate for these problems and others, workshops for Tunisians in the travel service industry are in the process of being arranged with Swiss hotel schools (Fieldwork 1987).

In terms of teaching modules information on the tourist industry is available through the Tunisian Embassy and UN publications such as the statistical yearbook. Students can map tourist origins, discuss their prior perceptions of Africa as a tourist place, discuss the pros and cons of a tourist industry (largescale or smallscale), compare and analyze tourist pictures and maps of different countries for their effectiveness. Moreover, they may draw generalizations that apply to the ever-growing tourist industry in West Virginia.

For those with a research interest in the travel and tourism industry, ideas include the cultural impact of the tourist on traditional societies, perceptions of the benefits of tourism by the host society, and the economic impact of such an industry. With a burgeoning tourist industry of our own in West Virginia, there are lessons to be learned from the Tunisian experience at all levels.

## Desertification

Deserts are everywhere enlarging their bounds (Hare 1976). Data from the Sahara were long interpreted as suggesting that the great desert was spreading southward. More recently, we have come to accept the fact that it is also spreading northward into the Arab countries (Worldwatch paper 13, 1977). A fieldtrip into the Tunisian sector of the Sahara confirmed the northward spread (Fieldwork 1987). Dunes can be seen building up in the Oasis of Kebili, and spilling across the road to Douz. In the less dramatic desert steppe area the observable impetus to the desertification process is poor land management, particularly in the form of the overgrazing of sheep and goats (Dregne, 1970). The major problem here, of course, is erosion as opposed to the spreading of sand.

The most obvious attempt to slow the spread of the Sahara in Tunisia is the creation of man-made dunes. In this strategy, palm fronds are placed in the ground ahead of the encroaching desert. As



sand piles up against the fronds they are moved higher. Eventually the sand breaks through and the palm fronds are moved to a new location.

In terms of teaching modules one might use the notion of bio-ecology, human ecology, and/or a worldwide context of desert phenomena for purposes of discussion. For example, what are the relationships between desert plants/desert animals and the environment? What is the relationship between people and the environment? Students may discuss the characteristics that desert environments have in common (including population characteristics), or the role of bio-engineering in developing a plant base that can slow down the process of desertification. Discussion can be further stimulated by the suggestion of a system of international governance based on a deteriorating environment.

Several questions arise for those with a research interest in desert environments. What data are available on plants that can slow the development of the desertification process? What is the ecology of these plants, i.e., are they palatable to people or animals? How will the development of a "green glue" to hold the dunes in place affect land management programs of more traditional societies such as Berber and Bedouin?

## Summary and Conclusions

This paper represents a sharing of experiences and ideas for those with a teaching and/or research interest in aspects of Tunisia, North Africa and the Arab World in general. It provides ideas for classroom instruction and research in terms of the diffusion of AIDS, Travel Industry and Desertification.

A listing of books and audio visual materials is available from several international studies or Arab studies centers in the eastern United States (FACDIS-West Virginia University, Middle Eastern Studies Program-University of Indiana, Middle East Center-University of Pennsylvania, Arabic Language Bilingual Materials Development Center-University of Michigan, Department of Judaic and Near Eastern Languages and Literatures, The Ohio State University).

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# Zoology Section

## Anatomy of a Dicephalic Calf


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### Abstract

A stillborn, dicephalic calf was delivered on a farm near Athens, West Virginia. The specimen had two heads and two separate necks. In the posterior region of each skull was an anomalous foramen, exposing the brains. A severe case of spina bifida was present in the lumbar region. The tracheae from the two necks converged to form a single trachea. The circulatory system was very abnormal. The heart was much broader in the ventral to dorsal dimension than side to side. Both atria were small, with the right atrium on the right anterior portion of the heart and the left atrium on the left posterior portion. The venae cavae were attached to the right atrium. The aorta emerged from the right ventricle and continued caudally on the right side of the body. The pulmonary trunk also emerged from the right ventricle. Several vessels of intermediate to small size and resembling veins, connected to the left ventricle, and were directed toward the left anterior region of the body. No vessels brought blood to the left atrium.


### Introduction

A fetus with two heads is referred to as dicephalus. Various studies have been conducted on dicephalic specimens, the majority of these being on bovines. Reportedly, 0.2 to 3.6 per cent of all calves born have congenital defects (Greene, 1976). Leipold (1972) discussed two

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newborn dicephalic calves, both having a heart defect, bilateral cleft palate, spina bifida, and kyphoscoliosis. Majeed (1971) described in detail all major systems of a double-headed buffalo calf. Pandey (1972) described a conjoint twin monstrosity in another buffalo calf. This research has now advanced to the level of attempting to explain the mechanism of partial twinning, *e.g.* Easton (1984). This paper will discuss the findings from the gross dissection of a dicephalic calf.

## Materials and Methods

A two-headed female Angus calf was born on a farm near Athens, West Virginia, several years ago. Delivery was by Caesarean section and the full term specimen was stillborn. It was obtained by the Biology Department of Concord College and preserved for future study. The dissection of the calf was completed during the spring of 1987, using standard dissecting tools, a Bowie knife, and a bone saw.

## Results and Discussion

### *External Appearance*

The preserved calf weighed 17.2 kg. It had two well developed heads, approximately equal in size, and two separate necks. The limbs were normal. The only additional abnormality visible on external inspection was a severe case of spina bifida, which protruded from the dorsal surface. All other structures appeared normal and unduplicated.

### *Skeleton*

There were many malformations of the skeleton, both axial and appendicular. The anterior axial skeleton was, for the most part, duplicated. There were two skulls, each with an extra foramen in the posterior region. These may have been the result of incomplete fusion of the cranial bones or simply a developmental anomaly. Brain tissue was present in each foramen. Articulating directly posterior to these extra openings were the two atlases. These joined a large vertebral structure which appeared to consist of the two axes fused together and this articulated to the single third cervical vertebra (atlodidymus). This arrangement paralleled the findings of Leipold (1972). Following these were the normal remaining cervical and thoracic vertebrae.

The spina bifida occurred in the lumbar region and was very severe. The sacral vertebrae were scoliotic. The thorax had a normal set of thirteen pairs of ribs, but was somewhat misshapen due to the spina bifida. The lumbar vertebrae in the region of the diaphragm extended deep into the visceral cavity, lowering the last pairs of ribs and deforming the shape of the thorax.

### *Axial Division*

The region between the heads contained a large, well developed, double-lobed thymus. There was one thyroid gland just anterior to each lobe of the thymus. Each was followed anteriorly by the thyroid cartilage and hyoid bone.

At the most anterior point of the junction between the heads, two pairs of muscular bands were present. One pair was directed medially between the heads. The other, posterior to the first pair, bifurcated, with one muscle band to the right head and one to the left. Also present on each side of these muscle bands were very large sublingual salivary glands.

### *Respiratory System*

The respiratory system was abnormal with anterior duplication. The two tracheae converged to form a single trachea which continued to the level of the pulmonary cavity and terminated. There was no apparent connection of the trachea to the lungs. The lungs, however, were developed, with the left lung being one-third the size of the right.

### *Circulatory System*

The circulatory system was the most abnormally developed of all of the systems studied. The normal mammalian heart is cone-shaped. The lower border of the heart forms a blunt point known as the apex, which points toward the left. The heart of this specimen was much broader in the ventral to dorsal aspect, and quite narrow in the medial aspect. The apex of the heart was oriented toward the right instead of the left.

The right and left ventricles were properly situated, but the atria were abnormal in position and size. Both atria were small, with the right atrium on the right anterior side, and the left atrium located on the left posterior portion.

Externally, the venae cavae were attached to the right atrium (Figure 1). The superior vena cava branched into many satellite veins

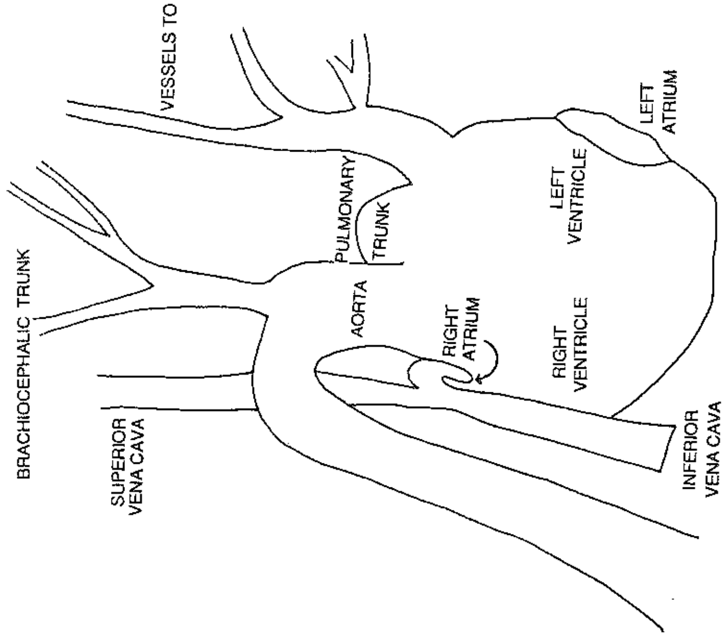


**Figure 1. Ventral view of heart**

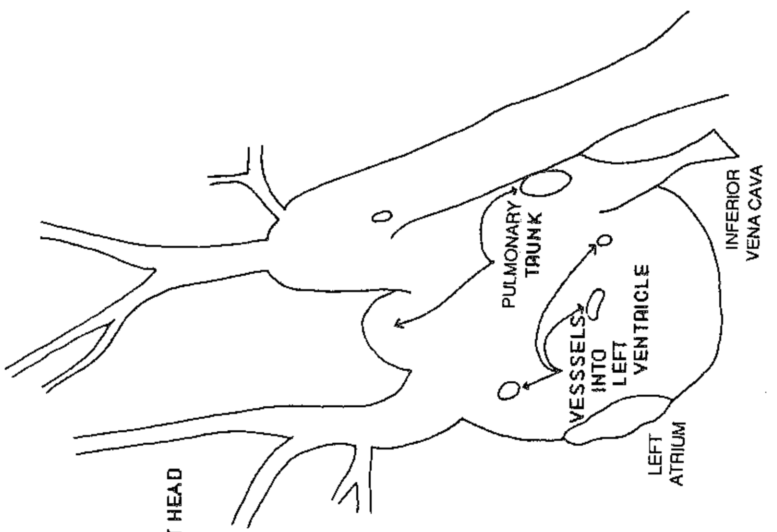


**Figure 2. Dorsal view of heart**



anteriorly. The inferior vena cava was attached posteriorly through the diaphragm to the liver.

The aorta emerged from the right side of the heart and was directed caudally on the right side of the body. From the aorta branched the brachiocephalic trunk, which traversed a path between the heads. The pulmonary trunk also emerged from the right side.

There were vessels of intermediate size, resembling veins, connected to the left side of the heart. These were directed toward the left head, neck, and shoulder regions.

Upon dissection, the internal structure of the heart reflected the anomalous external structure (Figure 1). A probe into the right ventricle revealed that the aorta was continuous with the right ventricle instead of the left ventricle. Also, the pulmonary artery branched dorso-caudally from the right ventricle.

The left ventricle was continuous with a branching vessel of intermediate size that communicated with the left anterior region. There were also smaller vessels connecting to the rear of the left ventricle (Figure 2). None of these had fully developed valves. No vessels brought blood to the left atrium. There was no apparent connection between the right and left sides of the heart, and there was no evidence of a foramen ovale. This may be consistent with the right ventricle serving the systemic circulation during the fetal stage.

This confusing arrangement of vessels gives rise to many speculations concerning the functioning of, and blood flow through, this heart. The vessels entering the left ventricle connected most conspicuously to the left head. Recall that the superior vena cava drained the right head. The right ventricle appeared to be the only functionally pumping chamber, with fully developed valves.


## Acknowledgements

Special thanks are due to Dr. L. E. Bayless, Dr. Carl J. Chapman and Dr. Karl D. Fezer of Concord College, for their valuable assistance and guidance.


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# State Records of Adult Micro-Caddisflies From West Virginia (Trichoptera: Hydroptilidae)

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**Abstract**

Based on an examination of adults and literature records, the first detailed investigation of the family Hydroptilidae, or micro-caddisflies, from West Virginia includes 13 species in five genera. Eleven species are state records. Included are important range extensions for *Neotrichia vibrans* Ross, *Ochrotrichia dardeni* Harris, *O. graysoni* Parker and Voshell, and *Hydroptila perdita* Morton. Based on adults from black light traps, the emergence period for the micro-caddisflies from West Virginia extends from 29 June, *Hydroptila grandiosa* Ross, to 30 September, *Stactobiella delira* (Ross).

## Introduction

The Trichoptera, or caddisflies, is a large order of aquatic insects with a world fauna of approximately 7,000 species (Brigham et al., 1982). Approximately 1,300 species have been described from North America. The family Hydroptilidae, or micro-caddisflies, contains 15 genera and 179 species in North America (Brigham et al., 1982).

Until the present investigation, only two hydroptilid micro-caddisfly species have been reported from West Virginia: *Ochrotrichia denningi* Blickle and Morse and *Stactobiella delira* (Ross) (Blickle, 1979 and Smith, 1969). Examination of adult micro-caddisflies from black light traps of Marshall University students has provided distributional and emergence information on eleven state records from West Virginia. After this investigation, five genera and 13 species of micro-caddisflies are known from West Virginia. The five genera (*Hydroptila* Dalman, *Neotrichia* Morton, *Ochrotrichia* Mosely, *Oxyethira* Eaton, *Stactobiella* Martynov) found in West Virginia are widely distributed over the continent.

## Results

*State Records

### **Hydroptila ajax* Ross

*Geographic range*: Fourteen states (IL, IN, KS, KY, MN, NY, OH, OK, OR, VA, WA, WI, WV, WY) (Anderson, 1976; Etnier, 1965; Hamilton and Schuster, 1978; Longridge and Hilsenhoff, 1973; Parker and Voshell, 1981; Peterson and Foote, 1980; and Resh, 1975). The adults emerged between 10 May and 27 September.

*West Virginia distribution:* Kanawha Co., Coal River, Brumfield farm near St. Albans, 27 September 1980; 2 females.

### **Hydroptila armata* Ross

*Geographic range:* Quebec and 17 states (AL, AR, IL, IN, KS, KY, MI, MN, NH, OH, OK, SC, TN, TX, VA, WI, WV) (Brigham et al., 1982; Edwards, 1966; Etnier, 1965; Etnier and Schuster, 1979; Hamilton and Schuster, 1978; Harris, 1986; Leonard and Leonard, 1949; Longridge and Hilsenhoff, 1973; McElravy and Foote, 1978; Parker and Voshell, 1981; Peterson and Foote, 1980; Resh, 1975; and Unzicker et al., 1970). The adults emerged between April and 27 September.

*West Virginia distribution: Hampshire Co., South Branch Potomac River near Romney, 27 August 1980; 5 females.*

### **Hydroptila delineata* Morton

*Geographic range:* Nine states (AL, IN, KY, MN, NY, SC, TN, VA, WV) (Brigham et al., 1982; Etnier, 1968, 1973; Harris, 1986; Parker and Voshell, 1981; and Resh, 1975). The adults emerged between April and October.

*West Virginia distribution:* Hampshire Co., 4 miles south of U. S. Route 50, 27 August; 1 male.



### **Hydroptila grandiosa* Ross

*Geographic range:* Fourteen states (AL, AR, IL, IM, KS, KY, MN, MO, OH, OK, TX, VA, WI, WV) (Etnier, 1965; Hamilton and Schuster, 1978; Harris, 1986; McElravy and Foote, 1978; Parker and Voshell, 1981; Resh, 1975; Steven and Hilsenhoff, 1984; and Unzicker et al., 1970). The adults emerged between May and 27 September.

*West Virginia distribution*: Kanawha Co., Coal River. Brumfield farm near St. Albans (29 June 1980, 1 female) (6 July 1980, 2 females;) (21 September 1980, 3 females) (27 September 1980, 28 females).

### **Hydroptila hamata* Morton

*Geographic range:* Twelve states (AL, KY, MI, MN, NY, OH, OR, SC, TN, VA, WI, WV) (Anderson, 1976 Brigham et al., 1982; Etnier, 1965; Etnier and Schuster, 1979; Harris, 1986; Leonard and Leonard, 1949; Longridge and Hilsenhoff, 1973; McElravy and Foote, 1978; Parker and Voshell, 1981; Peterson and Foote, 1980; Resh, 1975; and Steven and Hilsenhoff, 1984). The adults emerged between April and 14 September.

*West Virginia distribution:* Kanawha Co., Coal River, Brumfield farm near St. Albans, 14 September 1980; 1 male.

### **Hydroptila perdita* Morton

*Geographic range:* Ontario, Quebec and thirteen states (AL, AR, DE, IL, KS, KY, MI, MN, NY, OH, PA, WI, WV) (Etnier, 1965; Harris, 1986; Lake, 1984; Leonard and Leonard, 1949; Longridge and Hilsenhoff, 1973; Masteller and Flint, 1979; McElravy and Foote, 1980; Resh, 1975; and Unzicker et al., 1970). The adults emerged between 27 August and October.

*West Virginia distribution:* Hampshire Co., South Branch Potomac River near Romney, 27 August 1980; 8 males, 24 females.

### **Neotrichia vibrans* Ross

*Geographic range:* Ten states (AL, AR, KS, MN, NH, OH, SC, TN, VA, WV) (Brigham et al., 1983; Etnier, 1965; Etnier and Schuster, 1979;

Hamilton and Schuster, 1978; Harris, 1986; Huryn and Foote, 1981; Morse and Blickle, 1953; Parker and Voshell, 1981; and Unzicker et al., 1970). The adults emerged between May and October.

*West Virginia distribution:* Wayne Co., Dickson Dam, Twelvepole Creek, 13 September 1979; 1 male.

**Ochrotrichia dardeni* Harris

*Geographic range:* Two states (AL, WV) (Harris, 1986). The adults emerged between June and 27 August.

*West Virginia distribution:* Hampshire Co., South Branch Potomac River near Romney, 27 August 1980; 13 males.

**Ochrotrichia denningi* Blickle and Morse

*Geographic range:* Three states (ME, NH, WV) (Blickle, 1979).

*West Virginia distribution:* no county records.

**Ochrotrichia graysoni* Parker and Voshell

*Geographic range:* Three states (AL, VA, WV) (Harris, 1986; Parker and Voshell, 1980). The adults emerged between May and October.

*West Virginia distribution:* Kanawha Co., Coal River, Brumfield farm near St. Albans, 14 September 1980; 1 male.

**Ochrotrichia tarsalis* (Hagen)

*Geographic range:* Nine states (AL, AR, KY, MN, OH, SC, VA, WI, WV) (Brigham et al., 1982; Etnier, 1965; Harris, 1986; Huryn and Foote, 1981; Longridge and Hilsenhoff, 1973; Parker and Voshell, 1981; Resh, 1975; and Unzicker et al., 1970). The adults emerged between May and 1 October.

*West Virginia distribution:* Kanawha Co., Coal River, Brumfield farm near St. Albans, 14 September 1980; 1 male.



**Oxyethira pallida* (Banks)

*Geographic range:* Ten states (AL, DE, KS, KY, MN, OH, SC, VA, WI, WV) (Brigham et al., 1982; Etnier, 1965; Haag and Hill, 1983; Hamilton and Schuster, 1978; Harris, 1986; Lake, 1984; Longridge and Hilsenhoff, 1973; McElravy and Foote, 1978; Parker and Voshell, 1981; Peterson and Foote, 1980; and Resh, 1975). The adults emerged between 11 May and 27 September.

*West Virginia distribution:* Hampshire Co., South Branch Potomac River near Romney, 27 August 1980, 1 male.

**Stactobiella delira* (Ross)

*Geographic range:* Eighteen states (AL, AR, CO, ID, KS, KY, ME, NC, NH, OH, OK, SC, TN, VA, WI, WV, WY) (Brigham et al., 1982; Etnier, 1965; Etnier and Schuster, 1979; Hamilton and Schuster, 1978; Harris, 1986; Huryn and Foote, 1081; Longridge and Hilsenhoff, 1973; Morse and Blickle, 1953; Parker and Voshell, 1981; Smith, 1969; and Resh, 1975). The adults emerged from 23 April and October.

*West Virginia distribution:* Grant Co., Petersburg, 30 September 1944; 1 male.

## Acknowledgements

A special thanks to the following students for collecting micro-caddisflies: Toni and Kerry Bledsoe, Bernadine Brumfield, Bill Cremeans, and Paul Hill. The authors are grateful to Dr. Robert Kelley for identification of adults, and to Vickie Crager for typing the manuscript.

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# New Records for Some Land Snails in West Virginia

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Abstract

G. K. MacMillan's 1949 work "The Land Snails of West Virginia" was the first extensive paper to treat this group in the state. Very little work on the land snails of the state has been published since that time. The Field Museum of Natural History has recently (1985) published Leslie Hubricht's "The Distribution of the Native Land Mollusks of the Eastern United States." His work contains much new information about distribution patterns in West Virginia. The purpose of this paper is to give additional distribution records for the state; records are derived from material housed at the Marshall University Malacological Collections. New distribution records for 50 species are presented. *Deroceras reticulatum, Gastrocoptera procera,* and *Ventridens coelaxis* are recorded for the first time as occurring in the state.

## Introduction

Very little work on land snails had been done in West Virginia prior to the 1930's. The lack of roads and the resulting poor accessibility to much of the Mountain State more than likely deterred even the most stout-hearted early naturalists. Dr. Stanley Brooks collected and described *Triodopsis platysayoides* from Cooper's Rock State Park, Monongalia County, West Virginia in 1933. This species is still known only from the type locality and is currently listed as Endangered by the U. S. Fish and Wildlife Service. This discovery apparently stimulated others to do work in the state and the 1930's saw an influx of collectors whose names read like a Who's Who of Malacology. Among those collecting locally during this time were; Graham Netting, Charley Wurtz, Neil Richmond, Victor Sterki, Arnold Ortmann, Henry Pilsbry, Calvin Goodrich and Joe Morrison. Specimens were sent to institutions such as The Smithsonian, The Academy of Natural Sciences of Philadelphia, The Harvard Museum of Comparative Zoology, The University of Michigan Museum of Zoology, and the Carnegie



Museum. I have no knowledge of any specimens staying in the State of West Virginia.

Pilsbry's "Land Snails of North America North of Mexico" (based on all of the collections mentioned above) appeared in a four-volume work during the years of 1939-1948. Limited information about the snail fauna of West Virginia was contained in this publication. The first major work on land snails of this state was produced by Gordon K. MacMillan in his "Land Snails of West Virginia" (1949). There is much good information about distribution patterns in this paper but there may be errors that result from mis-identification of certain species, according to Leslie Hubricht (1987, pers. comm.).

Nothing of consequence has been done with the local snails for the last forty years. I began the Marshall University Malacological Collections in September of 1975. The collections have grown over the years and currently number over 17,000 cataloged specimens of all types of mollusks. There are approximately 1,000 lots of land snails representing all fifty-five counties of the state. Most of the papers that have come out of the collections have dealt with the bivalves. Leslie Hubricht's (1985) "Distribution of Native Land Mollusks of the Eastern United States" contains a wealth of information about snail distribution in West Virginia. As I looked over the paper I realized that even though Mr. Hubricht had obviously spent considerable time collecting in the state there were, in the Marshall collections, county records that he did not list. This paper is an outgrowth of that realization. Mr. Hubricht has stimulated me to work to fill in the obvious blanks in the whole picture of snail distribution patterns for West Virginia. Hopefully this will be the first in a series of papers that will continually update the available information on this subject.

There are several species within the state that deserve a more extensive investigation as they may very well be found in such small numbers as to qualify for a special designation as rare or of scientific interest. Future papers will deal with this important contemporary issue.

In the table below I have presented records for counties not listed in Hubricht's paper. If MacMillan has also recorded specimens from these "new"counties, I have designated that by underlining those counties.

## New County Records for Some Land Snails of West Virginia

*Anguispira alternata*
Berkeley, Jackson, Mason, Putnam

*Catinella avara*
Cabell, Wayne

*Cochlicopa morseana*
Cabell, Mason, Taylor

*Deroceras laeve*
Cabell, Greenbrier, Mason - previously reported only from Fayette County

*Deroceras reticulatum*
Cabell - not previously reported from West Virginia

*Euconulus fulvus*
Mason, Roane, Wirt

*Gastrocopta armifera*
Brooke, Putnam, Mingo

*Gastrocopta procera*
Cabell - first record for state, common in surrounding states

*Haplotrema concavum*
Gilmer, Jackson, Ritchie

*Hawaiia minuscula*
Cabell Jackson Mason

*Helicodiscus parallelus*
Cabell, Lincoln, Jackson, Mason, Mercer, Monongalia, Roane, Wayne, Wirt

*Hendersonia occulta*
Mercer

*Megapallifera mutabilis*
Wayne



*Mesodon appressus*
Clay, Logan, Summers, Wayne

*Mesodon panselenus*
Mason, Mercer

*Mesodon clausus*
Wayne - 3rd county for state, add to Berkeley and Fayette

*Mesodon rugeli*
Fayette - 4th county for state add to Mingo, McDowell and Mercer

*Mesodon inflectus*
Fayette - known only from Fayette, 2nd locality

*Mesodon mitchellianus*
Barbour, Boone, Cabell, Mason, Pleasants, Tucker, Wayne, Wood

*Mesodon pennsylvanicus*
Barbour, Cabell, Mason, Wayne

*Mesodon sayanus*
Grant, Putnam, Raleigh, Wayne

*Mesodon thyroidus*
Jackson, Roane, Summers

*Mesodon zaletus*
Cabell

*Mesomphix cupreus*
Doddridge, Mason, Ritchie

*Mesomphix inornatus*
Gilmer, Grant, Putnam

*Mesomphix perlaevis*
Gilmer, Ritchie

*Pallifera dorsalis*
Mason

*Paravitrea capsella*
Fayette, Mercer

*Philomycus carolinianus*
Cabell, Wayne

*Philomycus virginicus*
Cabell, Wayne - previously reported only from Logan Co.

*Pomatiopsis lapidaria*
Cabell

*Punctum smithi*
Fayette - known only from Fayette, second locality

*Pupoides albilabris*
Barbour, Marshall, Summers, Wayne

*Stenotrema fraternum*
Harrison

*Stenotrema edvardsi*
Preston

*Stenotrema hirsutum*
Braxton, Brooke, Cabell, Jackson, Mason, McDowell, Nicholas, Putnam, Wayne

*Stenotrema stenotrema*
Pocahontas

*Succinea ovalis*
Brooke, Wood

*Triodopsis albolabris*
Jackson, Roane

*Triodopsis denotata*
Mason

*Triodopsis dentifera*
Greenbrier, Taylor, Wayne



*Triodopsis fraudulenta*
Ohio

*Triodopsis juxtidens*
Jackson, McDowell, Tucker

*Triodopsis multilineata*
Mason - second record in addition to Wood Co., Blennerhassett Island

*Ventridens coelaxis*
Mercer - state record

*Ventridens gularis*
Cabell, Wayne

*Ventridens intertextus*
Mineral, Wood

*Ventridens ligera*
Hancock

*Ventridens suppressus*
Roane

*Ventridens theloides*
Mercer

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**Minutes of the Annual Business Meeting**
**West Virginia Academy of Science**
**63rd Annual Meeting**
**Room 128 Colson Hall**
**Salem College**
**Salem, West Virginia 26246**

April 2, 1988

Meeting called to order at 9:34 A. M., 26 members present.

Dr. Keller reported on the status of the Proceedings.

Dr. Keller moved, Dr. Taylor second -- change the By-Laws to extend the term of the president from one year to two years. Dr. Swiger asked for explanation of the need for the change. Discussion followed -- voice vote with all in favor -- Dr. Stephenson abstained.

Copies of the treasurers report were distributed by Dr. Clarkson. Dr. Keller moved, Dr. Pauley seconded that the report be accepted. Motion passed.

Report from the nomination committee -- Dr. Pauley, Dr. Keller, Dr. Taylor. Dr. Don Tarter nominated as president-elect. Dr. Swiger moved nominations be closed; Dr. Tarter elected by acclimation.

Dr. Keller moved, Dr. Pauley seconded that page charges be increased from 7.00 to 10.00 dollars; motion passed.

Dr. Taylor suggested that we need more advertisement to support the Proceedings. Dr. Keller indicated that advertisements brought in $345 in past year.

Dr. Stephenson moved that we begin publication of papers not presented at the meetings. Dr. Glenco indicated that such a move would require a By-Laws change. Dr. Stephenson amended his motion that a change in the By-Laws should be made to allow for publication of papers not presented at the meetings, Dr. Keller seconded. Discussion followed. Dr. Swiger pointed out that at least one of the authors needed to be a member in order to be published in the Proceedings and that she felt this requirement should remain. Motion passed.



Dr. Stephenson initiated discussion of the student outstanding paper award. Dr. Swiger indicated the need to examine possible ways of accomplishing this task. Dr. Taylor suggested a committee of three as in ASB and other organizations. Dr. Swiger asked that the papers not be removed from their sections. Dr. Tarter moved that a committee be created to set guidelines. Dr. Taylor second. Motion passed.

Dr. Glenco reported on the Westinghouse WV Science Talent Search.

--$14,000 awarded since 1948.
--Nationally, the history dates back to 1942 .
--all of West Virginia included since 1970.
--one West Virginia student placed in the honor group -- top 300 last year.
--Volume 58 of the Proceedings contains a description of the Talent Search Program.
--Dr. Glenco will present awards on April 8, 1988 at the State Science and Engineering Fair to be at Glenville State College.

Dr. Hennig asked that section moderators collect papers at the end of each session and return them to him.

Report on membership by Dr. Clarkson indicates a total of 292 members with 74 new members added this year. Dr. Clarkson indicated that Dr. Chisler should be commended for his efforts to increase membership.

With no further discussion the meeting adjourned.

Gary W. Snyder
Secretary

# WEST VIRGINIA ACADEMY OF SCIENCE
# ANNUAL TREASURER'S REPORT
# 1987

April 1-2, 1988
WVAS Annual Meeting
Salem College
Salem, West Virginia

January 1, 1987 to December 31, 1987

CASH RECEIPTS

| | | |
|---|---|---|
| Balance on Hand January 1, 1987 | | $10,597.71 |
| 30-day CD (redeemed 1/15/87) | $4,316.78 | |
| Dues | 1,745.00 | |
| Institutional Membership | 1,400.00 | |
| Proceedings (Libraries) | 1,190.00 | |
| Contributions (Talent Search) | 102.00 | |
| Annual Meeting | 237.00 | |
| Page Charges | 571.00 | |
| Interest (31-day CD) | 19.26 | |
| Interest (12-mo. CD) | 348.71 | |
| Interest (passbook) | 238.17 | |
| Advertisements | 345.00 | |
| Abstract Charges | 76.00 | |
| **TOTAL RECEIPTS FOR YEAR** | **$6,279.34** | |
| **TOTAL RECEIPTS & BALANCE ON HAND** | | **$21,186.63** |

CASH DISBURSEMENTS

| | | |
|---|---|---|
| Printing (McClain) | $8,387.25 | |
| Annual Meeting | 390.30 | |
| Postage | 141.72 | |
| National Assoc. of Academy of Science (dues) | 27.00 | |
| Miscellaneous | 333.68 | |
| Talent Search | 265.89 | |
| **TOTAL DISBURSEMENTS** | **$9,545.84** | |
| **BALANCE DECEMBER 31, 1987** | | **$11,640.79** |

(Savings (passbook) ---- $4,297.76)
(Checking ----------------- $1,741.79)
(Certificate of Deposit - $5,616.29)
(First National Bank of Morgantown
Acct. No. 001-D15809)

Respectively submitted,

Roy B. Clarkson, Treasurer, WVAS