Investigation Title: Utilization of ERTS-A Data in Geological Evaluation, Regional Planning, Forest Management, and Water Management in North Carolina

Proposal No. 18

Contract No. NAS5-21732

Principal Investigator: Charles W. Welby, Dept. of Geosciences, NCSU

Date: August 31, 1973

The objective of the contract is to demonstrate the usefulness of ERTS-1 data to various state agencies.

The period July-August has been spent in two ways: (1) continuation of contacts with various state and local agencies regarding use of ERTS-1 data in their functions and (2) specific project studies concerning use of ERTS-1 data.

In the case of the second activity, specific work on use of ERTS-1 data in mapping coastal features has been carried on and is still progressing. A second project, evaluation of density-slicing techniques for study of the Hofmann Forest test site and adjacent areas has been completed. A copy of the report is attached.

A copy of a paper presented at the International Symposium on the Interrelationships of Estuarine and Continental Shelf Sedimentation in Bordeaux, France, by the principal investigator accompanies this report. The figures summarize the slides used in the oral presentation.

Copies of ERTS-1 imagery at a scale of 1:250,000 have been made available to Dr. Robert Butler of the Geology Department at the University of North Carolina, Chapel Hill. He and his graduate students will use them in conjunction with a regional mapping program extending across the piedmont and mountain provinces of the western part of North Carolina and including the Asheville area. A report on the usefulness of the imagery for work undertaken during July through September should be received later in the year. Cooperation of the Cape Fear Technical Institute in groundtruth studies in the Wilmington area continues.

Future plans call for a concentrated use of ERTS imagery in study of the geology and soils of the state planning of Region J (Raleigh area) in part supported by the Office of Earth Resources, and the Winston-Salem area. Work will continue on ERTS imagery evaluation in the Wilmington area in conjunction with SKYLAB. Special emphasis will be placed upon coordinating the study with other on-going studies.

A major algae bloom has occurred late in August in the Chowan River area, and when the August 30 imagery is returned it will be studied in conjunction with multispectral camera data collected about a week later.

Funding of the project seems adequate at this time. Support from other sources is constantly being sought during the efforts to bring the ERTS-1 data to potential users.

NORTH CAROLINA ESTUARINE-SHELF COMPLEX --- PLEISTOCENE TO RECENT HISTORY

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Like many coastal regions the North Carolina coast has a diverse geologic history. Its present form and the present processes are influenced by what has gone before. The following discussion addresses itself to two aspects of the development of an understanding of the North Carolina coastal region. The first aspect is that of the post-Miocene geologic history; the second is that of present-day processes and the relation of the estuarine areas to the continental shelf.

Figure 1 shows the area being described. An important element in the discussion of the relations between the shelf and estuarine deposition is the presence of the well-known barrier islands, the "Outer Banks."

Post-Miocene History

Generalizing about the history of the North Carolina coast, it appears that during Late Pliocene to Early Pleistocene erosion took place. Streams incised themselves into the Late Miocene formations, and many of the major streams still follow the sites of this downcutting. Erosion developed an undulose surface on the Miocene and older beds.

As sea level rose during the Pleistocene, marine water crept up the stream valleys, and as the coastal area was inundated, sediment accumulated to greater thicknesses in the lower areas than in the topographically

higher ones. Some of the best records of Pleistocene events appear to lie beneath the waters of Pamlico Sound and adjacent areas. In general there is a seaward thickening of the post-Miocene section.

The Pleistocene sediments exposed on land record a mixture of marine and nearshore environments in an as yet incompletely deciphered pattern. So in a general way we see the Pleistocene recorded not too differently from what we find today, except that the margin of the sea lay farther inland than at the present.

A high resolution boomer study of the Pamlico Sound area has shown the presence of three post-Miocene unconformities in addition to the unconformity existing between the Late Miocene and Pleistocene sediments. Shideler and Swift (1972) describe a basal boundary reflector off the North Carolina and Virginia coasts at depths of 40 to 80 meters. The contours shown on their map can be interpreted as extension of the structural contours presented by Brown, Miller, and Swain (1972) for the top of the Late Miocene. The geophysical work in Pamlico Sound generally agrees with the subsurface interpretations of these authors. It thus appears that for much of the eastern one-half of Pamlico Sound that the top of the Miocene is between 50 and 60 meters below sea level.

The unconformities found beneath Pamlico Sound are best defined in the geophysical records on the basis of the edges of channels, but inclined bedding and locally cross-bedding also assist in their recognition. Swift and Shideler (1972) recognize in the Cape Hatteras to Cape Henry stretch of the shelf a set of unconformities which appear to correlate with those described in this report. They attribute the sedimentation in the lowermost post-Miocene sequence to fluvial processes and recognize the middle unit as

nearshore in origin. O'Connor and Riggs (1971) describe extensive channeling perpendicular to the coast in what appears to be the upper part of the sequence discussed here. They suggest fluvial and/or tidal activity as the cause of the channels.

One drill hole near Swanquarter on the northern shore of Pamlico Sound (Welby, 1971) clearly cut through the lower post-Miocene unconformity into the Miocene beds. The macrofossil assemblage in the beds immediately above the Miocene suggests a marine environment of at least 10 meters water depth. Other drill holes along the northern shore of Pamlico Sound indicate that much of the post-Miocene interval is marine with the exception of the upper 3 meters or so. The channeling, which is very prominent in many places, is believed to represent erosional events during periods of lowered sea level. The back-filling in the channels in the western part of Pamlico Sound can apparently be connected to deposits under present land areas, implying that much of the back-filling took place as sea level rose to cover the higher areas. In some places the bedding is suggestive of a deltaic environment.

No clear channel pattern throughout the sound has been discovered. However, near Ocracoke Inlet a pattern suggests that during each break in sedimentation channelized water flowed out onto the shelf area near the western end of the present Ocracoke Island (Fig. 1). Tidal channels in Ocracoke Inlet are an extension of this pattern.

In summary it appears that the Pamlico Sound area experienced at least three marine invasions prior to being shut off from the sea and developing its present configuration. The landward margins of these transgressions lay west of the present sound. One of these invasions is recorded by the Suffolk Scarp which is well shown in several satellite images of the area (Fig. 1).

It appears from drilling elsewhere in the North Carolina Coastal Plain that the oldest post-Miocene beds extend west of the Suffolk Scarp (Daniels and Gambel, personal communication, May, 1973) and that much of the post-Miocene record is pre-Wisconsin in age.

Present-Day Processes

Although today's shoreline activities do not necessarily duplicate those of the past exactly, we can get some appreciation of the energy relations and sediment transport patterns from today's circumstances. In recent years considerable study of coastal erosion has been undertaken and some long-term patterns of coastwise sand movement developed (Langfelder, et al, 1968). One recently completed study (Masterson, 1973) suggests that the net sediment movement through the inlets is associated with the ebb tide. Thus far, however, the coastal system has been studied piecemeal, and not all of the pieces have been fitted together. Repetitive satellite imagery has provided an opportunity to study some of the coastal processes synoptically.

ERTS-1 Imagery

Any number of air photographs exist which show sediment movement along the North Carolina coast and which show sediment plumes off Cape Hatteras, Cape Lookout, and Cape Fear. With the advent of the ERTS-1 satellite operating on its eighteen-day cycle, it has been possible to obtain imagery over a large area for different wind and tide conditions. Study of the ERTS-1 images taken since the fall of 1972 shows the strong influence that wind conditions have on sediment behavior in the estuaries as well as off-shore. Only a few examples can be presented here.

Wind and tidal conditions associated with the November 15, 1972, ERTS-1 pass over coastal North Carolina as well as the interpretation of the sediment

patterns seen on ERTS-1 image 1115-15152 are found in Fig. 2. The patterns taken from a density slice of the .5 to .6 micron band show the decrease in suspended material away from the Cape. The original image suggests not only a mushroom-like plume but also a southward drift at some depth below the surface.

Cape Hatteras and the sediment plumes adjacent to it are generally well known from the Apollo IX photographs. ERTS-1 has provided some interesting imagery of this area, including information on the behavior and migration of the Gulf Stream.

On December 2, 1972, January 25, and March 2, 1973, the Hatteras area was imaged. Figure 3 illustrates the tidal and wind data for the area on these dates, and Figure 4 is an interpretation of the ERTS-1 images. A southward drift from Oregon Inlet toward Cape Hatteras is suggested for the nearshore region in the original imagery. Sometime before the image was made local conditions caused the development of a northward arching of the Hatteras plume just offshore. The sediment is strung northeastward and apparently sharply sheared off by the west side of the Gulf Stream.

In the January 25, 1973, image of the area north of Cape Hatteras the sediment load is diffused. A faint northward arching pattern about 20 km offshore and in the same approximate position as for the December 2 image is present. A two-pronged pattern of sediment distribution lies about 50 km offshore.

The March 2 image shows the stretching of the Hatteras plume to the northeast, and interestingly enough, it shows the presence of at least two layers of suspended sediment. The long, finger-like northeastern part of the plume seems to be deeper in the water (a in Fig. 4) than the parts closer

to the shore. The image is interpreted as showing at least two periods of sediment injection into the system. The arching seen in the December and January images just north of Cape Hatteras does not seem to be present at this time. Figure 4 illustrates the several positions of the Hatteras plume at the different times. Shifting of the plume undoubtedly has had an effect upon the distribution of suspended material.

Details of the sediment distribution pattern in the Oregon Inlet area on March 2, 1973, is shown in Fig. 5. The flood tide delta at the inlet is visible as is the pattern of sediment concentration along the shore and offshore. It seems probable that the sediment concentration in the lower right hand corner of the figure represents a plume extending northward from Cape Hatteras.

Conclusion

In studying estuarine-shelf sedimentation, we often cannot pinpoint the dynamics of the system. Looking through drill holes and studying seismic information, we see the results of a complex matrix of events, the end result of the geologic events. Usually we look at only a small portion of a region.

ERTS-1 imagery gives an opportunity to see synoptically and repetitively the events that are going on over a large area and the dynamics of the system. In studying sediment transport from behind the barriers, we cannot ignore the fact that currents offshore act both longshore, toward land, as well as seaward. Our interpretation of geologic history must take these facts into account.

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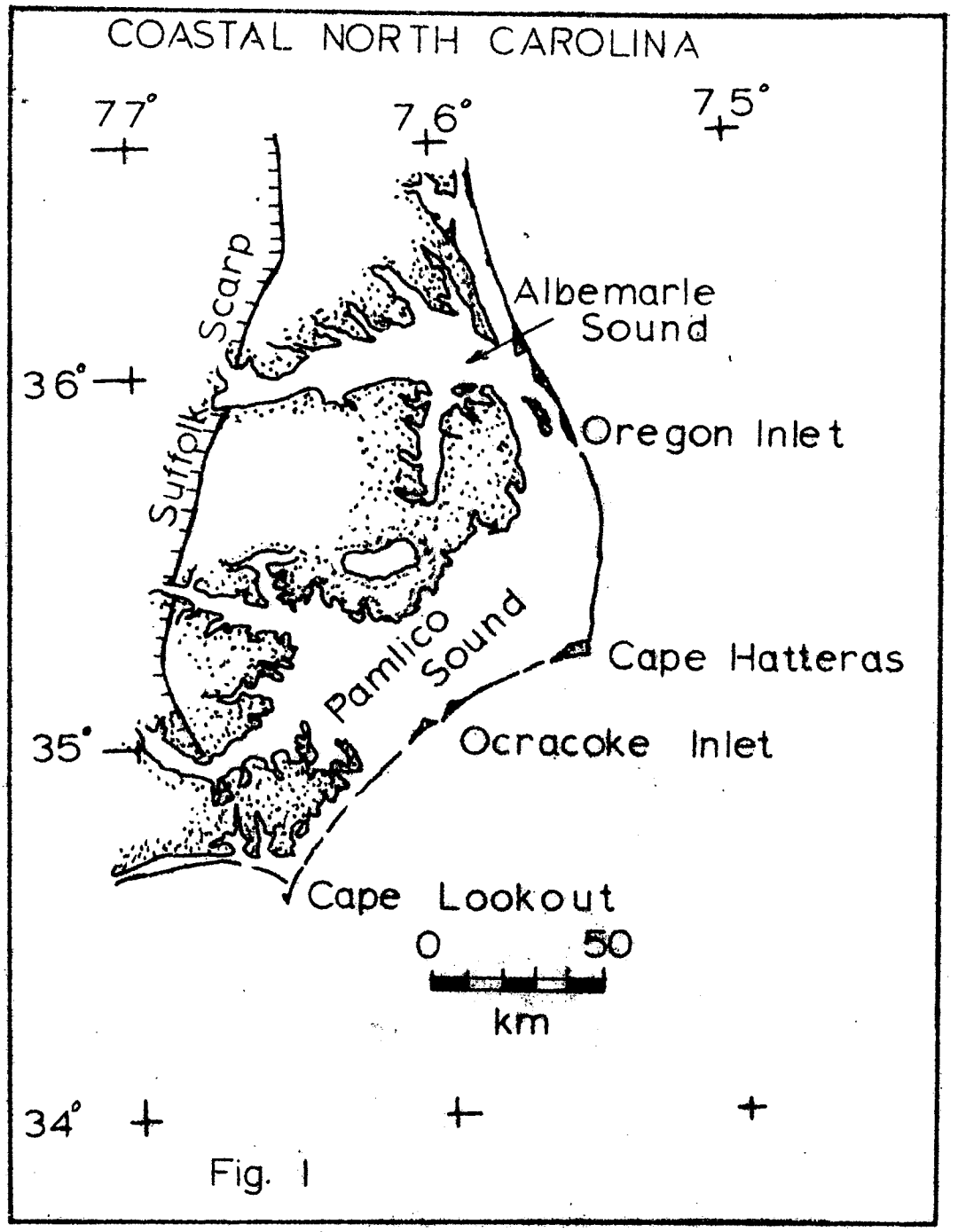
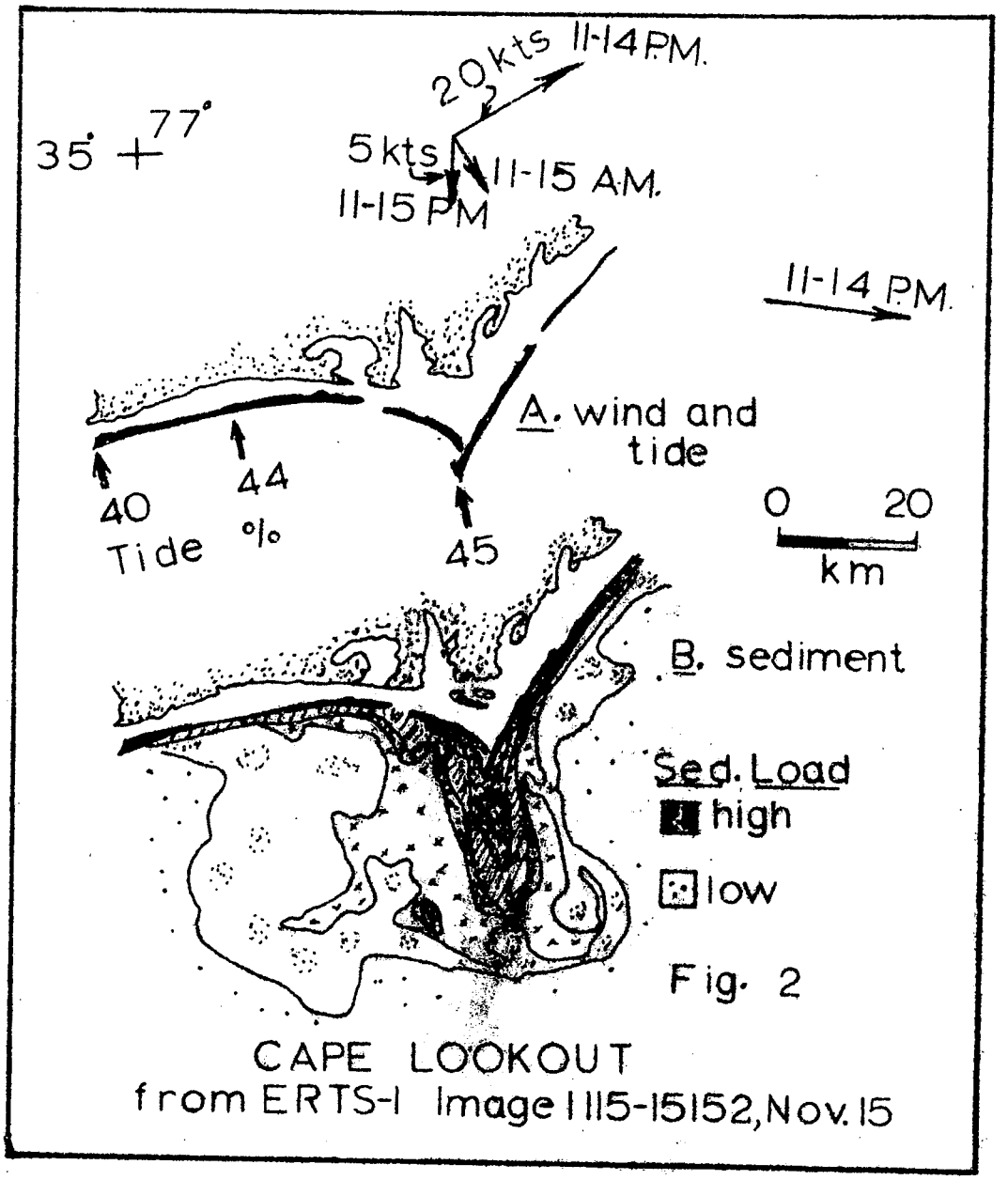

COASTAL NORTH CAROLINA
77°
76°
75°
36°
35°
34°
Suffolk Scarp
Albemarle Sound
Oregon Inlet
Pamlico Sound
Cape Hatteras
Ocracoke Inlet
Cape Lookout
0
50
km

Fig. 1


20 kts 11-14 P.M.
35° + 77°
5 kts
11-15 A.M.
11-15 P.M.
11-14 P.M.
A. wind and tide
40
44
45
Tide %
0 20
km
B. sediment
Sed. Load
high
low
Fig. 2
CAPE LOOKOUT
from ERTS-1 Image 1115-15152, Nov. 15

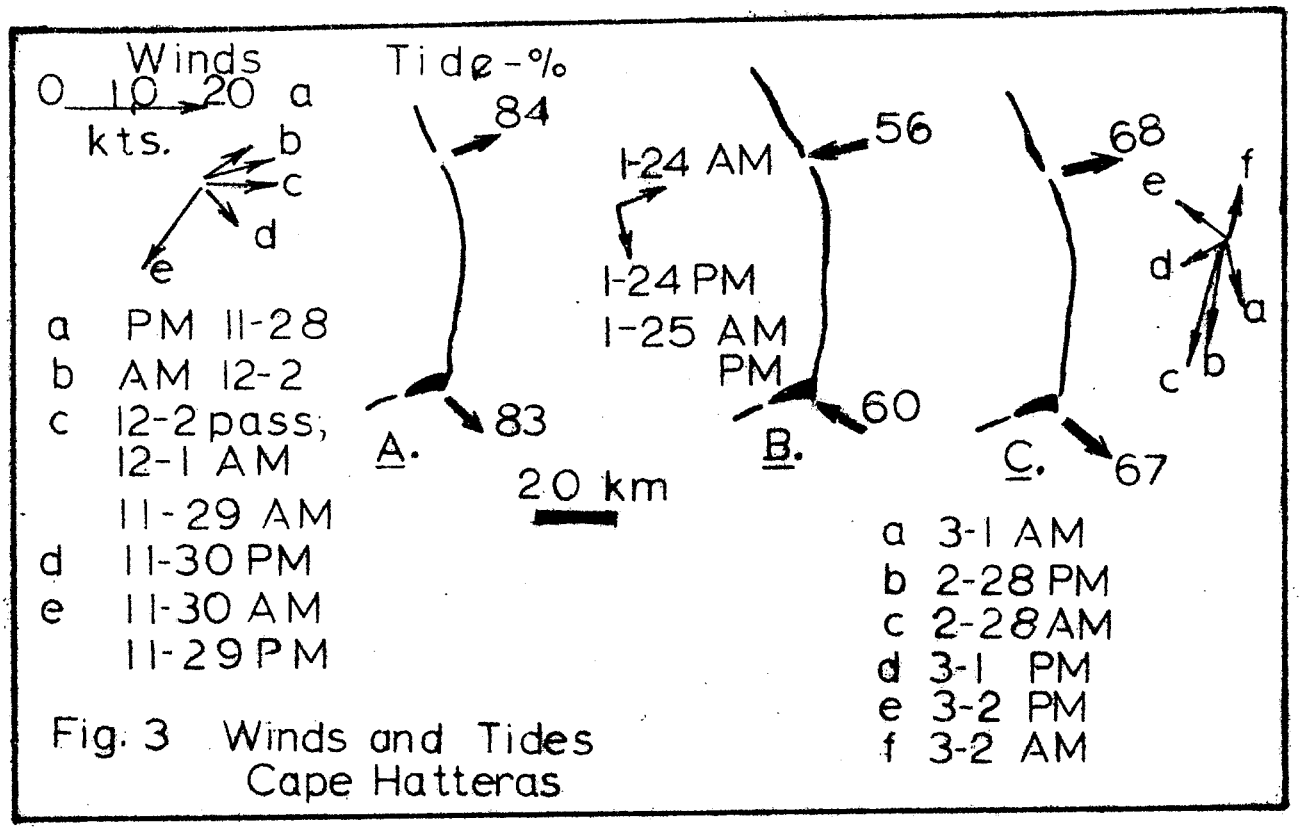
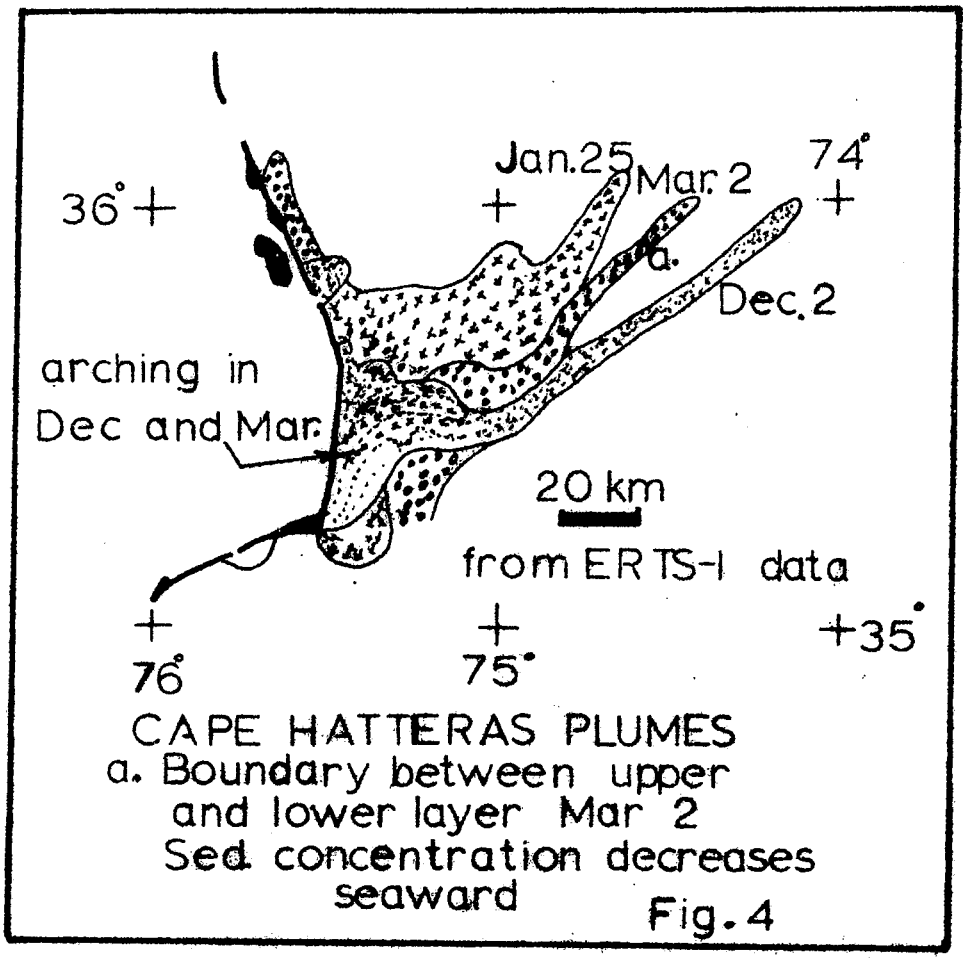
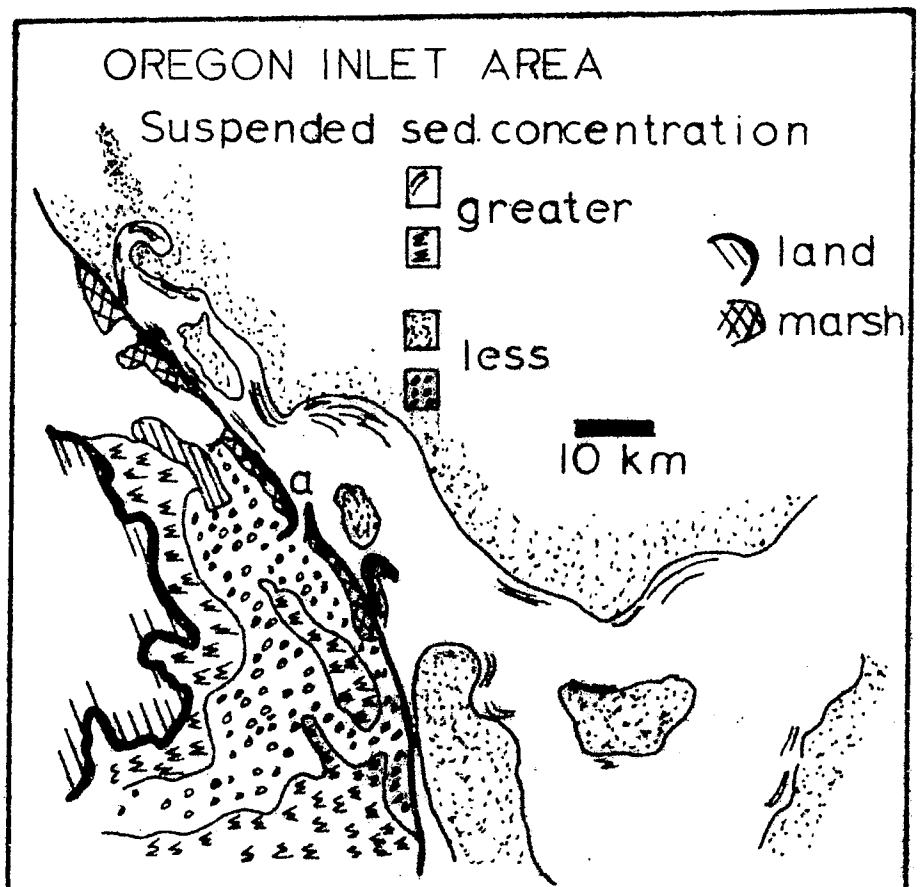


Fig. 3 Winds and Tides
Cape Hatteras



CAPE HATTERAS PLUMES
a. Boundary between upper and lower layer Mar 2
Sed. concentration decreases seaward

Fig. 4



a. Oregon Inlet and tidal delta
Fig. 5 ERTS-1 1222-15093
Mar. 2, 1973

THE UTILIZATION OF ERTS-1 IMAGERY FOR LAND-USE CLASSIFICATION AND DESCRIPTION IN THE EASTERN COASTAL PLAIN OF NORTH CAROLINA: ACTUALITIES AND POTENTIALITIES OF THE AVAILABLE DATA WITH SPECIAL REFERENCE TO THE USE OF DENSITY SLICES

REPORT OF JOHN L. WARREN

Introduction

This collection of ideas and findings is intended to serve two purposes. One is to explain what I have learned about the area in question and what I think should be done in the future. The second is to provide a starting point for anyone else who wishes to pursue the use of ERTS-1 imagery for land classification in this part of the state. If a graduate student happens to read this, please note that this area of endeavor is pregnant with dissertation possibilities that are entertaining as well as interesting-a combination very few students at N.C. State presently enjoy in their academic programs. Before detailing what's up, a brief outline of where and whom to get information from will be given.

Information Sources for E. Coastal Plain Land Use

The area studied in detail the most is as follows: From the Hofmann Forest in Jones and Onslow counties east to Cedar Island in Carteret County; From New Bern south to Swansboro and all land and water areas south of the Neuse River and North of Bogue Banks. This is a rather large area but full of diverse uses, some unique to this part of the United States. I concentrated my attention to the Hofmann Forest and the Central and Eastern half of Carteret County.

1. Hofmann Forest Information

The Hofmann Forest is owned by the North Carolina Forestry Foundation and leased to the Hoerner-Waldorf Corporation (formerly the Albemarle

Paper Company). Researchers are welcome and the staff will assist in any reasonable way. This writer was stuck on Plum Nearly Road 10 miles from anything; W.W. Wicks and help spent the better part of a Saturday trying to get me out. They are interested in what we are doing and very cooperative.

The manager is W.W. Wicks whose headquarters are in Deppe, on U.S. Highway 17 south of Maysville at the Hofmann Forest entrance. Any visit to the forest should go thru him or his assistant so that they will at least know you are there. In Raleigh there is little information available in print. A book about the history of the Hofmann Forest, THE HOFMANN FOREST, is available from the School of Forestry. It offers a general overview of what has happened up until a few years ago. Maps of the forest and its many roads are available in the ERTS lab. Numbered areas are keyed with general descriptions of what the particular area contains. This map should only be used as a rough approximation.

The best source of information on the Hofmann and its 78,000 acres is Dr. T.E. Maki, a walking photo of the place. He will help with any problems or questions and has some personal slides of the area which may be useful to those who have never been there. Dr. Maki also has extensive information on drainage research in pocosins and fire influences and control. The interested one is referred to FOREST FUELS ON ORGANIC AND ASSOCIATED SOILS IN THE COASTAL PLAINS OF NORTH CAROLINA. S.E. FOR. EXP. STA. BULL. 144, 1962.

This is a good summary of the different vegetation types and their fire potentials encountered in a pocosin. Also a Forest Service manuscript - THE HOFMANN FOREST FIRE by Ward and Nelson (copy available from Dr. Maki) is an excellent account of the 18,000 acre fire in May of 1972. For further information on pocosins consult Dr. Maki. An aerial photo composite of portions of the forest is available in the ERTS lab.

Note: Any one who intends to do much in this area of the state should make at least a preliminary field trip to the Hofmann or other pocosin. There is no adequate way to describe one until you have been in it and gotten the feeling of vast tracts of man-less lands. Also, careful ground-truth studies facilitate quick recognition of imagery differences.

2. Carteret County Information

County highway maps at a scale of 1"=2 miles are available for Carteret, Onslow, Jones, Pamlico, Craven. USGS maps are available at a 1: 250,000 scale for the area. (There are in the ERTS lab in Biltmore.) Extensive information on the Croatan forest and other areas in the area east of the Hofmann are available from Andy Weber or others in Forestry Extension. If they don't know, they know who does. If one is interested in coastal processes or estuarine problems the Duke Marine Lab in Beaufort is a fine resource. Also UNC has a Marine Resources Institute at Morehead City. The Duke Marine Lab is the cheapest place to stay in the area at less than $5/night. If lodging is desired contact Mary Fond Jones at the Duke Lab as far in advance as possible. Explain what you are doing and the need for a place to stay. Also, they are usually full at certain times of the year with students, so arrangements should be made at least a week in advance.

ACTUALITIES: What was actually done

Ground truth studies

As the author was not very familiar with the area many trips were made, one covering practically every paved road in Carteret County. Such evaluation and data gathering are essential before any interpretation of imagery or density slices can be meaningful.

General Highway Corridor Land Use Survey

Most major paved roads of the area were driven and the different land uses were noted. No detailed account of every use was attempted. Rather, major changes in use and/or cover type were noted as well as any distinguishing characteristic or unusual happening. I found that the main uses which could be noted or changed were: FOREST COVER, TIDAL MARSHES, AGRICULTURAL FIELDS, LOGGED AREAS, POCOSINS, URBAN AREAS, HOMES AND FIELDS, LAKES, GRASSY AREAS, SHRUBS, POWER LINES (IF WIDE ENOUGH), SITE-PREPARED AREAS, AIRPORTS, INTERSECTIONS, LARGE RECREATIONAL OR RESIDENTIAL DEVELOPMENTS, BOMBING RANGES, CANALS, BEACH DUNES. A map including Onslow, Jones, Craven, and Carteret counties contains a brief outline of these findings for roadways only. (Using county highway maps). Green-forested cover; Purple-urban and built-up areas; Red-bare agricultural fields or clearings (areas of high reflectance); Yellow-orange-areas of tidal marsh rivers or black-water swamps. Mileages are keyed to the car speedometer. Key to map includes mileages giving starting points so that any particular stretch can be accurately located on the county highway maps. Overlays were made using image 1205-15153-5 with the lantern slide projector for 70 mm negatives. By aligning the green crosses on the highway map with the red crosses on the overlay proper register can be achieved. An overlay using a density slice was not useful due to the vertical exaggeration (1.2 in the Y-axis) in the slices. This exaggeration will be present in all of the slices due to the curvature of the television screen from which the photo of the images is made. Hence, any mapping efforts must account for this difference by compensation.

Note that vast areas on the study area cannot be readily accessed by car due to poor road conditions or no-road conditions. However, reasonable ground-truth studies can be conducted using the highway-corridor approach and coupling it with use of aerial photographs, ERTS-1 imagery, high-altitude photography.

(Note: U-2 photos of the coastal areas along Bogue Sound are available; they are excellent and serve as "ground-truth" for one who has already been in the area to some extent.)

Based on this survey and other field-trips the following areas and/or cover types can be distinguished on ERTS-1 imagery; often enlargement is needed to a scale of 1: 125,00 to facilitate interpretation of the image. At scales much larger than this the enlarged image becomes too fuzzy for feasible use.

Areas Detectable on ERTS-1 Imagery

1. High schools and their adjacent athletic fields-usually areas of very high reflectance (often same reflectance as central portions of pocosins). Locations: 1 mile east of the intersection of US 70 and NC 101 on NC 101; at the intersection of US 70 and County Road 1238 in E. Carteret County, this area is quite large with many fields in addition to the high school and a boat-works to the east of the intersection.

2. Tidal marshes and rivers. Very prevalent in this area and are best seen and studied on infrared (BAND 6) or far infrared (BAND 7). On the keyed map they are yellow-orange and usually found where roads cross rivers or mouths of rivers into larger bodies of water influenced by the tides. Locations: many, a few are as follows - on US 70 east of Beaufort, from the intersection of US 70 and County Road

(CR) 1238 east on US 70 there are numerous tidal marshes where the road skirts the waters edge or crosses a tidal stream; also near the end of US 70 is Cedar Island National Wildlife Rufuge - about 8-10 miles of uninterrupted marshes and channels; on CR 1154 east of Newport are many beautiful marshes; on NC 24 west of its intersection with US 70 the road crosses many rivers; where NC 24 enters Swansboro at the White Oak River there are large expanses of tidal marshes.

3. Lakes. Many prominent lakes are in the area but must be interpreted with care as will be explained. The infrared bands are best for delineating these lakes and their surrounding wetlands where present. Locations: On CR 1154 east of Newport is a beautiful black-water lake and river, must be located with care as it is surrounded by fields and site prepared areas of high reflectance; Great Lake, Long Lake, Little Lake, and Lake Ellis Simon are in the eastern area of the Croatan Forest, these lakes are often very silty and do not always have definitely delineated boundaries. In density slices they are often similar in reflectance to the more turbid parts of the Neuse; Great Lake has a southern extension which is dammed off during the winter part of the year and planted with brown millet or other grain to serve as a source of feed for migratory waterfowl in the area; this damming can be readily seen in ERTS-1 imagery; Lake Ellis Simon appears to be filling in rapidly and should be field checked if feasible; in the western area of the Croatan, Catfish Lake is highly visible as a linkage between the two main pocosins in the Forest. CR 1100 west of US 70 can serve as an access to this area and I would suggest that the rangers for this area be contacted as some roads are often in very poor condition for car travel.

4. Agricultural fields. Numerous. At present no study of differences by crop has been done and the author has had no success in determining whether particular crops can be delineated. Most fields have high reflectances in the yellow range on density slices and the cyan range for less reflective fields.

5. Recreational or residential developments: detectable but need to know general location. SeaGate is visible (located on NC 101 at the Intracoastal Waterway bridge) on the west side of the waterway. This reflectance is accounted for due to the removal of the forest cover and the present of mainly sand and sandy beaches in the area.

6. Roads and Power lines: highly visible; power lines are usually straighter for longer distances and in areas of little population as along Roper Road in the Hofmann Forest (to be discussed later).

7. Airports: highly reflective and visible. Marine Corps Air Station at Cherry Point north of NC 101 and US 70.

8. Bombing Range: in east Carteret Count east of CR 1300 and north of US 70. Most highly reflective; we think this has been drained and is kept high and dry without substantial vegetation; further information as to ground cover should be sought from the Marine Base at Cherry Point if possible. This large square area is readily visible on all area images and photos.

9. Old beach scarps and ridges: most easily seen between CR 1141 and CR 1124 in Carteret County; readily visible as light colored streaks on images; further investigation should be done to determine the major causes in differences; appears to be differences in vegetation and hence reflectance but may be topographical as well.

10. Pocosins: these are unique features only found in the coastal areas of the Carolinas; basically a pocosin is a swamp on a hill - that is it is a wet area that is higher than surrounding areas; usually underlain by 20-60 inches of organic soil and then a rather impermeable clay lens which is dry. The cover vegetation is varied and can be of 3 types:

The low, open pocosin - low shrub species 1-3 1/2 feet high; on organic soil with 90+% organic matter and an organic layer 2 feet or more; principal species are swamp cyrilla, fetterbush, common gallberry, and honeycup. Overstory consists of widely scattered pond pine usually less than 15 feet in height; contains 3 years of brush and litter accumulation. OD weight 5.68 tons/acre.

The low, dense pocosin - shrub heights average 4 feet with principal species being swamp cyrilla, honeycup, fetterbush, common gallberry and widely-scattered clumps of loblolly-bay; overstory has widely scattered pond pine; denser due to brush growth and litter accumulation of about eight years. OD weight 8.45 tons/acre.

The high pocosin - plants average 14 feet high; on organic soils 18-24 inches thick; includes swamp cyrilla, loblolly-bay, common gallberry, and greenbrier; undisturbed brush growth and little accumulation for at least nine years. OD weight 15.00 tons/acre.

Pocosins have a very distinctive appearance on ERTS-1 imagery that is hard to explain to one who has not seen the imagery. They appear as "smudged" areas on the image.. This appears due to the gradations between the pocosin fringes and the central pocosin itself. As the center of the pocosin is approached the vegetation is different from the edges and exhibits greater reflectance.

Principal pocosins are as follows: East Cartaret County east of the bombing range; a small area between the bombing range and the CR 1300 (can be easily seen from CR 1300 north of its intersection with CR 1163); an area between the intracoastal waterway and CR 1300; between CR 1300 and CR 1700; in Croatan National Forest the lakes are separated by two large, distinctive pocosins; the Hofmann Forest in Onslow and Jones Counties (more on this later).

11. River Courses - particularly visible in the infrared bands, these areas can be traced due to the distinctive vegetation of the hardwood swamp types. Some of the more easily seen river bottoms are: the White Oak River - starts in the Hofmann Forest and ends in the Swansboro area; Pettiford Creek - feeds into White Oak from Croatan Forest; Hadnot Creek - feeds into White Oak from the Croatan; Newport River - west of Newport to the Newport River estuary north of Morehead City.

12. Logged and Site Prepared Areas: usually appear as areas of high reflectance similar to agricultural fields. Main areas are around the Hofmann Forest (to be discussed later) and in Eastern and North Central Sections of Carteret County, east of CR 1300 and Southeast of CR 1318.

13. Forests - forests appear as dense dark areas for the more mature types and dark gray for thinned or partly logged areas. Better delineation is given by the density slices and will be discussed later.

Detailed Examination of the Hofmann Forest Area

In addition to the highway-corridor land use survey an extensive study was made of the Hofmann Forest area in Jones and Onslow counties. Owned by the N.C. Forestry Foundation and leased to the Albemarle

Paper Company this 78,000 acre area has many access roads and artificial enhancements which lend it to study with ERTS-1 data. Further detailed study will be most useful and fruitful in this area. Areas such as the Hofmann which are predominantly pocosin and swamp vegetation are being bought at a rapid rate by paper and wood companies throughout North and South Carolina. The possibility that such areas can be mapped and examined utilizing ERTS-1 imagery would be of benefit to such operations as well to any proposed or planned State-wide Land Use Plan in which land classification would be a first and essential step. Pocosin areas are very difficult to navigate in and in some areas essentially closed to man. Remote sensing of such areas, particularly when coupled with density slicing, can be of value to government and private organizations. A review of what has been learned about this area utilizing ERTS-1 imagery and related data follows:

General

A map of the Hofmann is available with keyed number sections to orient the user. A large scale 1: 83,333 (approx.) photo of just the forest was made from image 1170-15205-5. This provides a synoptic view of the entire forest not available before and at such low cost. Such imagery can be repeated every 18 days and would be useful to the land manager once interpretations can be standardized. The most apparent uses are large man-made changes in the land cover. These are areas that have been recently site-prepared. Also the grass airport landing strip is visible as well as some experimental agricultural operations within the forest.

Roads - these are very visible and their appearance is enhanced by their contrast with adjacent land uses or cover types. Most roads are bordered by drainage ditches 3 feet wide and 3-6 feet deep with the water level 3-6 feet below the top of the road. Roper road (see Hofmann Forest Map) is bordered by a 150-foot-wide power line and right-of-way which is grassed. This is particularly noticed in images and the power line can be followed to the New Bern area. (as a parenthetical note - power companies and other utilities might be very interested in the utilization of ERTS-1 imagery for gross, preliminary planning for placement of power transmission lines or other utility corridors; coupled with appropriate density slices ERTS-1 imagery could greatly aid planning efforts).

Forests - appear as dense and darker than surrounding areas; in most areas loblolly and pond pine are present while hardwoods are found along the river courses and in swampy areas. Commercial forests can be clearly delineated in density slices.

Agricultural areas - the company is experimenting with various crops in large planted areas visible on images . In order to prepare the areas for use for crops the trees and associated vegetation are removed and then the top layer of organic roots and mats are burned. After all this and the removal of old stumps and roots the new field is 3-6 feet lower than the road running next to it. Thus, such areas are very wet if there has been any rain recently before the image was made. Materials not removed or burned are piled in large berms 4-10 feet high which run parallel to the length of the fields. In areas adjacent to the forest there are extensive agricultural activities particularly along the White Oak River which has its origin in the forest.

All imagery to date has been from winter and early spring. This should be compared with summer imagery and crops as soon as such imagery is available. The effects of the crops on the reflectance will be most interesting if there is any effect.

Site-prepared and recently logged areas - often appear same reflectance as agricultural fields although subtle differences can be detected on the density slice. Large areas to the west and south of the forest are being site prepared after clearcutting, followed by drum choppers, maybe burning and root raking and then plantings. Often some bare soil is exposed, though grass or other vegetation quickly grows back in this warm, humid climate. See the Hofmann Forest Map for these particular areas and their approximate location.

Pocosins - this is probably the most interesting aspect of the forest. As already mentioned pocosins have three general cover types and a very distinctive appearance on ERTS-1 imagery. The main pocosin area in the Hofmann Forest is known as the White Oak Pocosin and as the Big Opening. In May of 1972 a fire burned over 18,000 acres in this area with most of the damage in the pocosin area. Though wet large quantities of vegetation are maintained per acre and this can become very dry during periods of low rainfall and low precipitation such as April or May. Further study should seek to determine whether differences in fire intensity can be detected by ERTS-1 imagery. Fires in pocosins are frequent and images taken after a fire should be analyzed carefully.

After much study and looking at many images the pocosins stand out due to their extremely high degree of reflectivity. Only the Marine Corps bombing range in East Cartaret county is more reflective.

Considered opinion is that the reflectivity is due to a less dense overstory, pond pine occur rather far apart and the predominant ground cover is shrubs. Vegetation in a pocosin is different from non-pocosin vegetation in many ways. Further study should seek to determine if these differences in pocosins can be detected or are being detected in density slices.

Two characteristics are important in evaluating pocosin images; first, many species in pocosins are evergreens or semi-evergreens; secondly, many species have coriaceous leaves, that is their leaves have a leathery appearance which should increase the reflectivity of the vegetation.

In low, open pocosins, the following species composition is common:

Species	Percent	Evergreen	Coriaceous
Swamp cyrilla Cyrilla racemiflora L.	60%	x	x
Fetterbush Lyonia lucida	10%	x	x
Common gallberry Ilex glabra	10%	x	
Honeycup Zenobia pulverulenta	10%		
Greenbrier Smilax laurifolia & rotundifolia		x	x
Leatherleaf Chamaedaphne calyculata		x	
Redbay Persea borbonia (L.) Spreng.	10%	x	
Pond pine sprouts Pinus serotina Michx.		x	

Low, dense pocosin species composition

Species	Percent	Evergreen	Coriaceous
Swamp cyrilla Cyrilla racemiflora L.	35%	x	x
Honeycup Zenobia pulerulenta	35%		
Fetterbush Lyonia lucia	15%	x	
Common gallberry Ilex glabra	10%	x	
Greenbrier Smilax lauriflora & rotundiflora		x	x
Chokeberry Aronia arbutifolia			
Redbay Persea borbonia (L.) Spreng.		x	
White Bay Magnolia virginiana L.	5%	x	x
Bracken Fern Pteridium aquilinium			
Sheep Laurel Kalmia angustifolia		x	x

High Pocosin species composition

Species	Percent	Evergreen	Coriaceous
Swamp cyrilla Cyrilla racemiflora	50%	x	x
Loblolly-bay Gorgonia lasianthis (L.) Ellis	25%	x	x
Common gallberry Ilex glabra	15%	x	
Greenbrier Smilax lauriflora & rotundiflora and other shrubs	10%	x	x

NOTE: This type has a medium-density pond pine overstory and much needle drape.

Summary:

Pocosin Type	Percent Evergreen	Percent Coriaceous
Low, open pocosin	90%	62-67%
Low, dense pocosin	61-64%	36-39%
High pocosin	95-100%	80-85%

Difference between these types of pocosin cover are noteworthy. Study should be furthered to determine whether ERTS-1 imagery coupled with density slices can distinguish these different areas. More on this when we talk about density slices. At present it it very difficult to sample any pocosin areas. Any technique that enables this to be done with a minimum of ground truth will be rewarding.

DENSITY SLICING: RESULTS AND PROSPECTS

Basically density slicing is the following: a black and white negative composed of many shades and gradations of gray is placed in the density slicer. The machine has a range of 32 colors that it can substitute for different shades of gray. By careful manipulation an image of the black and white negative is produced in color. The operator is able to control the color inputs and to black out selected portions of the spectrum. Thus, if only water is to be studied those land areas can be blacked out to enhance the water differences.

The colors are arranged as follows:

Lightest tones:	Yellow 1-4	(each color has four steps) or shades or hues of that color
	Cyan 5-8	
	Green 9-12	
	Orange 13-16	
	Magenta 17-20	
	Violet 21-24	
	Red 25-28	
Darkest shades of gray:	Blue 28-32	

The colors the machine uses have no meaning in and of themselves. Rather they are arranged in this order to provide maximum contrast between uses which have similar shades of gray or similar reflectances. Density slices have been made of the following areas:

Raleigh-Durham	1243-15265-5 1099-15261-6 1207-15263-6,4,5
Asheville	1137-15380-5,4,6 1299-15280-4,5,6,7
Manteo	1070-15084,5,6 1132-15092-5,7,6 1222-15093-4,5,6,7 1186-15090-5,4,6
Hofmann Forest	1115-15152-5,6,4,7
Core Banks New Bern & Neuse River	1205-15153-4,5,6
Albermarle & Pamlico Sounds	1133-15150-5,6,7 1205-15150-4,5,6

For particular study five density slices were chosen and examined closely to determine what could be gleaned from this. Correlations were sought between aerial photographs, high altitude imagery, ERTS-1 data, and field trips in the areas covered. The areas and slide num-

bers (Numbers are based on Dr. Welby's key; supposedly each slide has been numbered and identified) are as follows:

Slide I-9 Hofmann Forest Enlargement
1115-15152-5 15 Nov 72

Slide V-IIA Hofmann Forest Enlargement
1205-15153-4 13 Feb 73

Slide V-15 New Bern & Neuse River Enlargement
1205-15153-6 13 Feb 73

Slide V-21 East Carteret County Enlarged
1205-15153-6 13 Feb 73

Slide V-13 East Carteret County Enlargement
1205-15153-4 13 Feb 73

DETAIL ANALYSIS OF SELECTED DENSITY SLICES

Slide I-9 Hofmann Forest Enlargement 1115-15152-5 15 Nov 72

This density slice is made from an ERTS-1 image that covers Eastern North Carolina from New Bern to Cape Lookout and from approximately Jacksonville to the Northern shores of the Neuse River where it empties into the Pamlico Sound. The scale of the enlargement is approximately 1: 83,333 and is centered on the Hofmann Forest. The density slices computed the following percentages of total area for the different colors:

Light yellow	6.2%
Dark yellow	6.1%
Dark Cyan	9.1%
Dark Green	12.5%
Orange	16.4%
Light Magenta	20.7%
Violet (changed to black)	20.1%
Light Blue	4.1%

Light yellow - includes the following areas known by direct observation or other remote sensing data:

- bare agricultural fields
- recently site prepared areas; some bare soil is exposed in such areas

- areas that have been site prepared and planted with young seedlings; seedlings not over 2 feet tall
- areas in organic soils, e.g. in pocosins that have been cleared and prepared for crops; generally bare land

Darker yellow -

- only a few areas are this shade, generally they are within or on the fringes of the lighter yellows
- includes portions of bare agricultural fields
- areas recently clearcut and logged; some bare soil
- portions of areas recently cleared and planted with stock two feet tall

Dark Cyan - the following areas were cyan:

- hardwood forests along the White Oak River leading out of the Hofmann Forest; NOTE: this photo was made in November and should be compared with one made during the summer
- thinner parts of the pocosin with higher reflectivities
- grassy areas; such as the air strip near Deppe in the Hofmann Forest
- site-prepared areas with little or no bare soil
- recently logged areas now planted in young plantations

Dark Green-Orange -

- these two areas could not be sufficiently delineated to be considered as separate colors and hence, land uses
- generally, these colors represent areas that are more densely vegetated but not completely forested

Magenta - more densely vegetated areas than green or orange but less than black and red

- power lines; as the one that borders Roper Road in the eastern half of the Hofmann Forest
- some roads; depending on the vegetation bordering the roads and the contrast

Black (Violet) Red -

- these areas are mature, densely populated stands with a high degree of crown closure; NOTE: may also include areas of thick brush and undergrowth

Slide V-IIA Hofmann Forest Enlargement
1205-15153-4 13 Feb 73 32 steps (no colors blacked out)

Yellows - including both light and darker yellows

- high reflectivity areas
- central area of pocosins
- bare soil and areas recently site prepared areas
- agricultural areas

Cyans -

- areas clearcut within the past year
- areas with denser, less reflective, vegetation; such as borders around pocosins
- grassy area such as near Hofmann Forest landing strip
- water courses; particularly evident in area south of the Hofmann where there is much disturbed land except along river banks

Greens - denser vegetation than previous colors

Oranges - logged hardwoods; such as on Plum Nearly road near the big bend
- much residual timber is still standing in these logged areas

Magenta & Violet
- hardwood stands
- dense pine stands; such as 36 yr. old plantation at Deppe

Blue - very dense stands with rather complete crown closure

Slide V 15 New Bern & Neuse River Enlargement
1205-15153-6 13 Feb 73 (all colors)

Light Yellow -
- areas of highest reflectivity within pocosins
- some agricultural lands with high reflectance

Dark Yellow -
- pocosin areas
- air base at Cherry Point
- few scattered agricultural areas

Cyan & Green -
- most agricultural fields not included with the yellows
- cut-over woodlands
- mixture of fields, forests, and small farm houses

Dark Green & Orange - dense stands of timber

Magenta & Red - water areas; note that lakes in Croatan Forest have different shades of reflectivity and probably water quality

Slide V-21 E. Carteret County Enlargement
1205-15153-6 13 Feb 73

Area Percentages

Oranges:	Step 16	12.3%	Greens:	Step 12	2.4%
	Step 15	4.0%		Step 11	3.2%
	Step 14	2.7%		Step 10	5.2%
	Step 13	2.4%		Step 9	8.5%
	Total	21.4		Total	19.3

Light Yellow
Dark Yellow - bombing range
-pocosins
- some bare agricultural fields

Cyans - agricultural fields (lighter cyan)
- some forests (darker cyan)

Green - forests

Oranges - tidal marshes near shores and inland

Slide V-13 E. Carteret County Enlargement
1205-15153-4 13 Feb 73

Yellow - pocosins
- especially reflective fields
- bombing range

Cyan - fields
- common mixture of farms, fields, forests, and homes

Green - Morehead City business district and close in residential sections
- forests

Oranges - dense pine forests
- tidal marsh at west end of Newport River near Morehead City

Magenta - some tidal marshes; maybe a qualitative species difference between tidal marshes that are magenta and those that are in orange range

Future efforts might do as follows: using 8-16 colors in the density slicer, a large area should be surveyed. Then when areas of particular interest are delineated they can be zeroed in on, using a wider range of colors with many steps. Thus, one might proceed from the entire eastern part of the state, to a particular county, to a specific pocosin in which many differences could be determined.