COLORADO COLLEGE:

THE BLOCK PLAN

AND

UNDERGRADUATE RESEARCH

WITHIN THE CURRICULUM

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COLORADO COLLEGE

COLORADO COLLEGE IS AN INDEPENDENT, COEDUCATIONAL COLLEGE OF LIBERAL ARTS RECOGNIZED AND ACKNOWLEDGED FOR ITS OUTSTANDING COMMITMENT TO UNDERGRADUATE EDUCATION AND ITS INNOVATIVE ACADEMIC LEADERSHIP IN THE WEST. THE COLLEGE WAS ESTABLISHED IN 1874 AND TODAY ENROLLS AN AVERAGE OF 1850 STUDENTS WHO ARE TAUGHT BY 140 FULL-TIME FACULTY, ALMOST ALL OF WHOM HOLD THE PH.D. OR EQUIVALENT TERMINAL DEGREE IN THEIR RESPECTIVE FIELDS. APPLICATIONS FOR ADMISSION TO COLORADO COLLEGE FAR EXCEED THE NUMBER OF STUDENTS ACCEPTED FOR ENROLLMENT. SAT SCORES FOR ENTERING FRESHMEN AT COLORADO COLLEGE CONSISTENTLY REMAIN AT LEAST TWO HUNDRED POINTS ABOVE THE NATIONAL NORM.

ALTHOUGH COLORADO COLLEGE HAS NO GRADUATE PROGRAM IN SCIENCE, STUDENTS ARE CONSISTENTLY AND ACTIVELY INVOLVED WITH FACULTY IN HIGH QUALITY RESEARCH PROJECTS. A MAJORITY OF THESE STUDENTS ATTEND GRADUATE SCHOOL AND RECEIVE ADVANCED DEGREES.

COLORADO COLLEGE'S POSITION AMONG THE NATION'S LEADING INSTITUTIONS FOR THE UNDERGRADUATE TRAINING OF SCIENTISTS IS DUE TO A NUMBER OF FACTORS, NOT LEAST IN IMPORTANCE IS THE NATURE OF THE TEACHER/STUDENT RELATIONSHIP. CLASSES ARE LIMITED TO A MAXIMUM OF 25 STUDENTS, WITH AN ACTUAL AVERAGE OF 14 STUDENTS PER CLASS. OF THE TOTAL ENROLLMENT AT COLORADO COLLEGE, TWICE AS MANY STUDENTS TAKE SCIENCE COURSES AS THE NATIONAL AVERAGE.

THE BLOCK PLAN

COLORADO COLLEGE'S ADOPTION IN 1970 OF A DISTINCTIVE CURRICULAR FORMAT KNOWN AS THE BLOCK PLAN HAS LED TO A UNIQUE TEACHING ENVIRONMENT WITH SPECIAL OPPORTUNITIES FOR RESEARCH. THE ACADEMIC YEAR IS DIVIDED INTO EIGHT THREE AND ONE HALF WEEK BLOCKS. FACULTY AND STUDENTS PARTICIPATE IN ONLY ONE COURSE AT A TIME, WHICH ALLOWS FACULTY TREMENDOUS FREEDOM IN EMPHASIZING LECTURE, LABORATORY OR FIELD STUDIES IN A COURSE. THE BLOCK PLAN BENEFITS STUDENTS BY PERMITTING THEM TO FOCUS ENTIRELY ON THE SUBJECT AT HAND, OFFERING THEM A CHANCE TO WORK CLOSELY WITH FACULTY, AND INCREASING OPPORTUNITIES FOR FIELD WORK, STUDY ABROAD, AND RESEARCH ENDEAVORS.

GEOLOGY AND THE BLOCK PLAN

I. FIELD-ORIENTED CLASSES

A. THE PROGRAM

THE BLOCK PLAN PERMITS COLORADO COLLEGE TO OFFER A GEOLOGY PROGRAM WHICH IS EXTRAORDINARILY FIELD ORIENTED, INCORPORATING DAY-LONG FIELD TRIPS IN THE LOCAL COLORADO FRONT RANGE, WEEK-LONG CAMPING TRIPS THROUGHOUT COLORADO, NEW MEXICO, UTAH, ARIZONA, AND WYOMING, AND EXTENDED TRIPS EVEN FURTHER FROM CAMPUS (MICHIGAN, CALIFORNIA, HAWAII, AND COSTA RICA).

INTRODUCTORY GEOLOGY CLASSES SPEND NEARLY HALF THEIR TIME OUTDOORS. STUDENTS SEE EXAMPLES OF VARIOUS ROCK TYPES AND THEIR STRATIGRAPHIC AND STRUCTURAL RELATIONSHIPS, AND PREPARE ONE OR MORE MAPS OF LOCAL GEOLOGY. UPPER-LEVEL CLASSES ALSO EMPHASIZE FIELD EXPERIENCES WHICH COMPLEMENT THE DEPARTMENT'S LABORATORY EQUIPMENT. THIS PAST YEAR, FOR EXAMPLE, THE IGNEOUS PETROLOGY CLASS STUDIED OUT-CROPS IN YELLOWSTONE AND CRATERS OF THE MOON NATIONAL MONUMENT, THE STRATIGRAPHY CLASS EXAMINED SECTIONS IN DEATH VALLEY, CALIFORNIA; THE STRUCTURAL GEOLOGY CLASS MAPPED ROCKS IN ARCHES NATIONAL PARK, VOLCANOLOGY WAS TAUGHT IN HAWAII, AND THE METAMORPHIC PETROLOGY AND FIELD GEOLOGY CLASSES TRAVELED TOGETHER THROUGH NORTHERN MICHIGAN AND MINNESOTA.

B. TIME COMMITMENT

AN ENORMOUS AMOUNT OF FACULTY TIME IS INVOLVED IN ORGANIZING FIELD TRIPS. STUDENTS, ALSO, MUST BE COMMITTED TO TIME AWAY

FROM CAMPUS. INTRODUCTORY GEOLOGY CLASSES, WHICH ARE TAUGHT IN TWO CONSECUTIVE BLOCKS, USUALLY INCLUDE 50 ACTUAL HOURS OF LECTURE, 50 HOURS OF LAB, AND NEARLY 150 HOURS OF FIELD TIME. A ONE-BLOCK UPPER LEVEL CLASS (E.G., IGNEOUS PETROLOGY) USUALLY INCLUDES 30 HOURS OF LECTURE, 40-50 HOURS OF LAB, AND AS MUCH AS 80 HOURS OF FIELD WORK.

C. COLLEGE SUPPORT

COLORADO COLLEGE'S COMMITMENT TO FIELD-ORIENTED LEARNING IS AT LEAST TWO-FOLD. A FLEET OF VEHICLES INCLUDING TWO GREYHOUND BUSES, FOUR 15-PASSENGER VANS, AND SEVERAL STATION WAGONS, AS WELL AS TWO FULL-TIME DRIVERS AND SEVERAL MECHANICS, ARE AVAILABLE TO DEPARTMENTS. THE ANNUAL FIELD TRIP BUDGET IN GEOLOGY IS NEARLY EQUIVALENT TO THE SALARY OF AN ADDITIONAL INSTRUCTOR.

II. RESEARCH OPPORTUNITIES IN GEOLOGY

A. THE PROGRAM

ALL STUDENTS ARE ENCOURAGED TO ENGAGE IN ORIGINAL SCIENTIFIC RESEARCH. THIS MAY OCCUR IN ANY OF THREE FORMS. FIRST, STUDENTS MAY WORK ON PROJECTS FOR WHICH FACULTY HAVE OBTAINED OUTSIDE FUNDING. SECOND, IN FULFILLING THE SENIOR THESIS REQUIREMENT, STUDENTS MAY UNDERTAKE THEIR OWN RESEARCH OR EXPAND ON PREVIOUS WORK WITH FACULTY AND COMMIT BLOCKS OF TIME TO THIS RESEARCH DURING THE SCHOOL YEAR. THIRD, OUR CURRICULUM IS EVOLVING TO INCORPORATE ORIGINAL RESEARCH PROJECTS INTO REGULAR CLASSROOM TEACHING. EXAMPLES FROM EACH OF THESE THREE FORMS ARE PRESENTED BELOW.

B. COLLEGE SUPPORT

RESEARCH UNDER THE BLOCK PLAN IS SUPPORTED BY THE COLLEGE'S COMMITMENT TO ACQUISITION OF EXCELLENT INSTRUMENTATION, BY THE FLEXIBILITY OF THE BLOCK PLAN, AND BY SMALL, CAMPUS-WIDE COMPETITIVE GRANTS.

1. THE FACILITIES

THE GEOLOGY DEPARTMENT HAS THIN SECTION EQUIPMENT AND A LEITZ PETROGRAPHIC MICROSCOPE WITH A CAMERA ATTACHMENT. ROCK CRUSHING AND POWDERING FACILITIES ALLOW THE PREPARATION OF SAMPLES FOR CHEMICAL ANALYSIS. OUR X-RAY LAB INCLUDES A DIFFRACTOMETER, POWDER AND SINGLE-CRYSTAL CAMERAS, AND A NEW RIGAKU WAVELENGTH-DISPERSIVE X-RAY FLUORESCENCE SPECTROMETER FOR MAJOR- AND TRACE-ELEMENT ANALYSES. THESE FACILITIES ARE

COMPLEMENTED BY ATOMIC ABSORPTION IN OUR CHEMISTRY DEPARTMENT AND BY NEUTRON ACTIVATION FACILITIES AND MASS SPECTROMETERS AVAILABLE AT THE U.S.G.S. IN DENVER. THE GEOLOGY DEPARTMENT ALSO HAS A SEDIMENTOLOGY/GEO-MORPHOLOGY LAB, AND EQUIPMENT FOR SEDIMENT AND SOIL ANALYSIS. THE DEPARTMENT HAS A TRIAXIAL ROCK DEFORMATION APPARATUS FOR ROCK DEFORMATION STUDIES. THE DEPARTMENT'S PROJECTING BINOCULAR SCOPE FOR MORPHOLOGICAL STUDIES, AND A DIGITIZER FOR IMAGE ANALYSIS, ARE COMPLEMENTED BY SCANNING AND TRANSMISSION ELECTRON MICROSCOPES IN THE BIOLOGY DEPARTMENT. GEOPHYSICAL EQUIPMENT INCLUDES A GRAVITY METER, A 12-CHANNEL SEISMOMETER, AN ELECTRICAL RESISTIVITY METER, AND A PROTON PRECESSION MAGNETOMETER. FINALLY, WE HAVE EXTENSIVE ROCK, MINERAL, FOSSIL, MAP, AND AIR PHOTO COLLECTIONS, AND FIELD SAMPLING AND SURVEY EQUIPMENT FOR TEACHING AND RESEARCH.

2. BLOCK PLAN TIMING

STUDENTS TAKE FULL ADVANTAGE OF THE BLOCK PLAN IN PURSUING RESEARCH. THEY ARE ABLE TO DEVOTE INDIVIDUAL RESEARCH BLOCKS TO THEIR PROJECTS AS NEEDED DURING THE ACADEMIC YEAR. THEY ARE ABLE TO TAKE BLOCKS OFF TO WORK ON PROJECTS. EACH OF THE GEOLOGY FACULTY DEDICATES ONE BLOCK TO WORKING WITH STUDENTS ON RESEARCH, ALTHOUGH MOST FACULTY ALSO MEET WITH STUDENTS REGULARLY THROUGHOUT THE YEAR. SIMILARLY, STUDENTS ARE NOT LIMITED TO ONE BLOCK OF RESEARCH BUT ALSO HAVE THE OPTION OF EXTENDING THEIR RESEARCH OVER A FULL SEMESTER IF NECESSARY.

STUDENT RESEARCH BLOCKS MAY BE USED FOR TRAVEL TO DO FIELD WORK, TO COLLECT DATA IN THE LABORATORY, OR TO WRITE UP RESULTS. GIVEN THE FLEXIBILITY OF THE BLOCK PLAN, IT IS NOT SURPRISING THAT MANY STUDENTS BEGIN THEIR RESEARCH WITH TRAVEL. IN RECENT YEARS, OUR STUDENTS HAVE WORKED AT MOUNT ST. HELENS, IN THE JEMEZ VOLCANICS OF NEW MEXICO, AND IN THE SANTA CATALINA MOUNTAINS OF ARIZONA. THEY HAVE MADE ON-SITE STUDIES OF NEOTECTONICS OF THE GRAND TETONS, ESTUARINE SEDIMENTATION IN THE GULF OF CALIFORNIA, CRETACEOUS PALEOENVIRONMENTS IN SOUTH AFRICA, AND VOLCANO MONITORING IN NEW ZEALAND. THEY HAVE WORKED ON VOLCANIC AND STRUCTURAL PROJECTS IN COSTA RICA, ANDESITIC VOLCANICS AT 18,000 FEET IN MEXICO, AND ON UNDERSTANDING MAGMA MIXING AT YELLOWSTONE AND SKYE, SCOTLAND.

3. FINANCIAL SUPPORT

COLORADO COLLEGE OFFERS TWO IN-HOUSE COMPETITIVE GRANT PROGRAMS THROUGH WHICH STUDENTS MAY RECEIVE SUPPORT FOR A PROJECT. FIRST, FACULTY MAY SEEK RESEARCH AND DEVELOPMENT FUNDS WHICH CAN BE USED TO PAY STUDENTS WHO ARE ASSISTING WITH FACULTY PROJECTS. THESE PROJECTS OFTEN LEAD STUDENTS TO CONTINUE WITH THEIR OWN RESEARCH AND FREQUENTLY CULMINATE WITH STUDENT CO-AUTHORED PAPERS. SECOND, STUDENTS MAY SEEK COLLEGE-SPONSORED VENTURE GRANT FUNDS, UP TO $800 PER YEAR WHICH CAN BE USED, FOR EXAMPLE, TO SUPPORT RESEARCH, OR FOR TRAVEL TO MEETINGS.

GENERAL COMMENTS

1. ROLE OF TEACHING

THE INTERACTION BETWEEN TEACHING AND RESEARCH IS OFTEN DISCUSSED BY DEPARTMENTS AND ADMINISTRATORS. AT COLORADO COLLEGE, WE HAVE BEGUN TO CONNECT THESE TWO ASPECTS OF A STUDENT'S EDUCATION IN OUR REQUIRED CLASSES. FACULTY TAKE STUDENTS ON FIELD TRIPS WHICH INVOLVE AREAS WHERE FACULTY RESEARCH IS IN PROGRESS. SOME LABS AND FIELD PROJECTS ARE ARRANGED SO THAT STUDENTS DO NOT MERELY REPRODUCE WORK OF PRECEDING YEARS. RATHER, FIELD WORK IS PLANNED SO THAT STUDENTS WILL GATHER NEW INFORMATION. THIS INFORMATION CAN THEN BE SET IN A LARGER CONTEXT BY THE INSTRUCTOR, ALLOWING STUDENTS TO SHARE IN THE EXCITEMENT OF THE SCIENTIFIC APPROACH.

SELECTING PROJECTS WHICH ARE NOT ONLY INTERESTING AND SIGNIFICANT BUT ALSO WHICH CAN INVOLVE AN ENTIRE CLASS (OR CLASSES OVER THE YEARS) IS A PURSUIT NOT OFTEN SUPPORTED BY GRANTING AGENCIES. BY INVOLVING AN ENTIRE CLASS IN A RESEARCH PROJECT, THE POSSIBILITY OF TURNING AN OTHERWISE UNREMARKABLE STUDENT INTO AN INTERESTED, SOLID SCIENTIST WITH PROJECTS 'THAT COUNT' IS GREATLY INCREASED. COLORADO COLLEGE'S BLOCK PLAN MAKES SUCH INCREASED PARTICIPATION LEVELS POSSIBLE.

2. THE PREREQUISITES

THE ACQUISITION OF GOOD EQUIPMENT (OR MANAGEABLE ARRANGEMENTS TO SHARE EQUIPMENT WITH OTHER INSTITUTIONS) IS A HIGH PRIORITY IN ESTABLISHING A SCIENCE CURRICULUM WHICH DOES NOT SIMPLY TELL STUDENTS ABOUT SCIENCE BUT ENGAGES THEM IN INTERESTING PROJECTS. IN A PETROLOGY RESEARCH PROJECT, FOR EXAMPLE, STUDENTS MIGHT BE INVOLVED IN FIELD WORK, MICROSCOPE ANALYSIS, OR GEOCHEMICAL WORK. IT WOULD BE EXTREMELY DIFFICULT FOR A SCHOOL TO INTEGRATE TEACHING AND RESEARCH IF IT DID NOT HAVE ADEQUATE EQUIPMENT TO SUPPORT EACH OF THESE PARTS OF A RESEARCH PROJECT.

ALL SOPHISTICATED EQUIPMENT, HOWEVER, IS USELESS UNLESS A FACULTY MEMBER IS WILLING TO CREATE AND PURSUE APPROPRIATE PROJECTS. IT IS CRITICAL THAT THESE PROJECTS BE SUPPORTED, AND IT IS UNFORTUNATE IF THEIR SCOPE OR DURATION ELIMINATES THEM FROM CERTAIN GRANT COMPETITIONS. ARE WE BETTER OFF HAND-PICKING A VERY FEW PEOPLE AS FUTURE SCIENTISTS OR SHOULD OUR CURRICULA BE MORE EFFECTIVE IN ENCOURAGING AND INSPIRING THOSE STUDENTS WITH NEWLY EMERGING POTENTIAL?

3. NEED FOR SUPPORT

AS UNDERCLASSMEN PARTICIPATE IN UNDERGRADUATE RESEARCH PROJECTS, THE NATURE OF THE CLASSROOM ITSELF MUST CHANGE. FACULTY NEED TO REVISE LABS AND LECTURES TO

INCLUDE NEW RESEARCH THAT ENABLES STUDENTS TO SHARE IN THE EXCITEMENT AND DISAPPOINTMENTS ASSOCIATED WITH SCIENTIFIC PROGRESS. FACULTY NEED TO ESTABLISH CLOSER TIES WITH PROFESSIONALS IN THE FIELD IN WHICH CLASSES ARE WORKING (E.G. INDUSTRY, U.S.G.S., ETC.). SUCH CONNECTIONS MAY BE USED TO DEVELOP PROJECTS, COMBINE RESOURCES AND BENEFIT ALL PARTIES. SUCH PROJECTS SHOULD NOT REPLACE SOUND ACADEMIC TRAINING BUT RATHER ENHANCE IT. FINANCIAL SUPPORT FOR FACULTY UNDERTAKING SUCH REVISIONS WOULD BE VERY USEFUL. IN ADDITION, STUDENTS NEED SUPPORT FOR SUCH ITEMS AS TRAVEL AND LABORATORY EQUIPMENT TO PURSUE PROJECTS. THESE NEEDS REPRESENT BUDGET ALLOCATIONS NOT OFTEN FOUND IN MOST UNDERGRADUATE DEPARTMENT BUDGETS. IF WE WISH TO ATTRACT AND INTEREST MORE STUDENTS IN SCIENTIFIC ENTERPRISES, SUPPORT FOR CURRICULUM REVISION AND STUDENT INVOLVEMENT, ALTHOUGH MINIMAL, IS ESSENTIAL.

THIS PLAN SUGGESTS THAT ALL STUDENTS, NOT JUST A FEW HAND-PICKED SENIORS, SHOULD HAVE THE OPPORTUNITY TO ENGAGE IN RESEARCH; THAT SUCH RESEARCH SHOULD FIRST BE ENCOUNTERED BY STUDENTS IN THEIR SOPHOMORE AND JUNIOR YEARS; AND THAT THIS APPROACH WILL BETTER PREPARE SENIORS TO UNDERTAKE RESEARCH OF HIGH QUALITY. SUPPORT OF DEPARTMENTS ATTEMPTING SUCH TRANSITION IS ESSENTIAL.

PROJECTS FUNDED THROUGH FACULTY EFFORTS

FACULTY WHO ARE ABLE TO OBTAIN FUNDING FOR A RESEARCH PROJECT FROM A GRANTING AGENCY (SEE THE SUMMARY ARTICLE BY DIANE SMITH IN THE JANUARY 1988 CUR NEWSLETTER) HAVE PROVIDED TREMENDOUS IMPETUS FOR STUDENT INVOLVEMENT IN BOTH RESEARCH AND PUBLICATION. HOWEVER, FACULTY HAVE THE POTENTIAL TO EXCLUDE INTERESTED STUDENTS AND MAY NOT REQUIRE THE STUDENT ASSISTANT TO PARTICIPATE IN THE DIFFICULT EXPERIENCE OF CREATING A GOOD PROJECT. A GOOD EDUCATOR MUST AVOID THESE DRAWBACKS. EXAMPLES OF PROJECTS IN THIS CATEGORY AT COLORADO COLLEGE INCLUDED IN THE FOLLOWING LIST ARE 1) THE NSF-SUPPORTED ANALYSIS OF EVOLUTION IN LAKE TANGANYIKA, AFRICA (DR. COHEN IS PRESENTLY AT THE UNIVERSITY OF ARIZONA), 2) THE W.M. KECK FOUNDATION CONSORTIUM-SUPPORTED STUDENT RESEARCH, AND 3) COLORADO COLLEGE-SUPPORTED RESEARCH OF A SMALL PROJECT IN THE WET MOUNTAINS IN SOUTHERN COLORADO.

EXPERIMENTAL STUDIES OF DECAPOD-GASTROPOD INTERACTIONS AT LAKE TANGANYIKA: IMPLICATIONS FOR A PREDATOR-PREY COEVOLUTION

KELLY WEST AND ANDREW S. COHEN

SINCE MOST LAKES ARE EPHEMERAL ON AN EVOLUTIONARY OR GEOLOGIC TIME SCALE, EFFECTIVE DISPERSAL AND COLONIZATION MECHANISMS ARE MORE CRITICAL THAN BIOTIC INTERACTIONS IN DIRECTING LACUSTRINE FAUNAL EVOLUTION. PREDATOR-PREY INTERACTIONS AND ADAPTATIONS IN PARTICULAR, TEND TO BE HIGHLY GENERALIZED FOR MOST LAKE FAUNAS. THE UNUSUAL, ENDEMIC, DECAPODS, CICHLID FISH AND PROSOBRANCH GASTROPODS OF LAKE TANGANYIKA, AFRICA, HOWEVER, DEVIATE FROM THIS NORM, DISPLAYING HIGHLY SPECIALIZED MORPHOLOGIES, SUGGESTIVE OF PREDATOR-PREY COEVOLUTION.

STUDIES OF PREDATOR-PREY INTERACTIONS WERE UNDERTAKEN TO INVESTIGATE THIS PHENOMENON. AQUARIUM STUDIES OF PREDATION UPON FOUR SPECIES OF SNAILS (SPEKIA ZONATA, LAVIGERIA NASSA, NEOTHAUMA TANGANYICENSE, AND PARAMELANIA DAMONI) BY THE CRAB PLATYTELPHUSA ARMATA, WERE PERFORMED TO EVALUATE THE EFFICACY OF PUTATIVE ANTIPREDATION ADAPTATIONS (ON THE PART OF THE SNAILS) AND PREDATION ASSISTING ADAPTATIONS (ON THE PART OF CRABS). THIS WORK SHOWS THAT LARGE SIZE, THICKENED APERTURAL LIPS AND ENHANCED SHALL SCULPTURE AMONG GASTROPODS ALL EFFECTIVELY DETER DECAPOD PREDATION. COMBINED AQUARIUM AND SHALL CRUSHING EXPERIMENT DATA INDICATES THAT SHELL STRENGTH IS NEGATIVELY CORRELATED WITH PREDATION BOTH BETWEEN SPECIES, AND BETWEEN DIFFERING MORPHS OF THE SAME SPECIES. COMPARISONS OF SHELL MASS-LOAD STRENGTH GROWTH TRAJECTORIES SUGGESTS THAT THE TANGANYIKAN SNAILS EMPLOY DIFFERENT GROWTH STRATEGIES IN PREDATION DETERRENCE, DEPENDENT UPON THE DEGREE OF THEIR JUVENILE GROWTH PHASE EXPOSURE TO PREDATION.

PREVIOUS STUDIES OF MARINE SYSTEMS (VERMEIJ, 1977; SIGNOR AND BRETT, 1984) SUGGEST TIMESPANS OF 10S TO 100S OF MA FOR THE DEVELOPMENT OF PREDATOR-PREY COEVOLUTIONARY COMPLEXES. THE TANGANYIKAN SYSTEM (MAXIMUM AGE-LATE MIO.) REDUCES THIS ESTIMATE BY AT LEAST AN ORDER OF MAGNITUDE.

]987 Geological Society of America annual meeting

PROCESSES OF ORIGIN AND ALTERATION OF FLUVIAL FACIES IN THE LEBO MEMBER OF THE FORT UNION FORMATION (PALEOCENE), CUSTER COUNTY, MT

CONSTANCE CAMERON HAYDEN, 1988

THE 1987 KECK CONSORTIUM SUMMER RESEARCH PROJECT IN SOUTHEASTERN MONTANA CONCENTRATED ON PALEOCENE FLUVIAL STRATA EXPOSED ALONG THE POWDER RIVER, LOCATED 25 MILES EAST OF MILES CITY, MT. IN THIS STUDY, ANCIENT FLUVIAL ARCHITECTURE AND LATERAL CLAY MINERALOGY VARIATIONS WITHIN THE FLUVIAL SYSTEMS WERE LOOKED AT IN DETAIL. THE INFORMATION GAINED HAS LEAD TO CONCLUSIONS ABOUT THE PALEOCLIMATE AND OTHER CHARACTERISTICS OF THE AREA AT THE TIME OF DEPOSITION.

SAMPLES WERE SYSTEMATICALLY COLLECTED FROM THREE DIFFERENT FLUVIAL SYSTEMS AND ANALYSED BY AN X-RAY DIFFRACTOMETER. FROM THESE DATA THE RELATIVE PERCENTAGES OF CLAY SPECIES, SPECIFICALLY SMECTITE AND KAOLINITE, WERE DETERMINED. IN EACH OF THE THREE RIVER SYSTEMS, THE ABUNDANCE OF SMECTITE DECREASED FROM CHANNEL TO FLOOD PLAIN WHILE KAOLINITE INCREASED.

TO EXPLAIN THE LATERAL VARIATION FOUND WITHIN THE FLUVIAL SEDIMENTS, THE STRUCTURES OF THE TWO PHYLOSILICATE MINERALS AND THE TYPES OF ENVIRONMENTS IN WHICH THEY ARE TYPICALLY FOUND MUST BE DISCUSSED. KAOLINITE HAS A VERY SIMPLE STRUCTURE AND IS FORMED IN WELL-LEACHED AREAS HIGH IN ORGANIC CONTENT WHERE PERALUMINOUS MINERALS (E.G. MUSCOVITE, MICROCLINE) ARE BEING WEATHERED UNDER TEMPERATE, HUMID CONDITIONS. ON THE OTHER HAND, SMECTITE HAS A VERY COMPLEX STRUCTURE AND IS FOUND IN SEMI-ARID, POORLY DRAINED AREAS LOW IN ORGANIC CONTENT (LOEFFLER, 1987).

SMECTITE, BECAUSE IT IS UNABLE TO FORM IN AREAS OF HIGH WATER MOVEMENT, YET IS FOUND IN CHANNEL DEPOSITS, IS LABELED DETRITAL. KAOLINITE IS LABELED AUTHIGENIC DUE TO THE FACT THAT SEM PHOTOS REVEAL EUHEDRAL BOOKS OF KAOLINITE EXISTING IN THE FLOOD PLAIN. THUS, SMECTITE-RICH CLAYS FROM THE CHANNEL WERE DISTRIBUTED ACROSS THE FLOOD PLAIN DURING FLOOD EVENTS AND WERE THEN ALTERED TO KAOLINITE BY LEACHING. THE PRESENCE OF ROOT CASTS AND OTHER PLANT DEBRIS IS EVIDENCE OF A SOURCE OF HYDROGEN IONS TO ALLOW LEACHING OF SMECTITE TO KAOLINITE. THIS ALTERATION WILL EXPLAIN THE INITIAL DISTRIBUTION OF CLAY MINERALS BY FAVORING THE PRODUCTION OF KAOLINITE AT THE EXPENSE OF SMECTITE IN THE GEOCHEMICAL CONDITIONS THAT EXISTED IN THE FLOOD PLAIN ENVIRONMENT 65 MILLION YEARS AGO.

MAFIC AND GRANITIC HYPABYSSAL INTRUSIVES, EAST-CENTRAL WET MOUNTAINS; NEWLY RECOGNIZED UNITS FROM THE MID-PROTEROZOIC ANOROGENIC SILVER PLUME EVENT, COLORADO

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MAPPING ALONG SOUTH HARDSCRABBLE CREEK IN THE WET MOUNTAINS HAS REVEALED THE EXISTENCE OF TWO FORMERLY UNRECOGNIZED INTRUSIVE BODIES OF THE MID-PROTEROZOIC ANOROGENIC SILVER PLUME EVENT. GRANITIC SILL-LIKE INTRUSIONS WERE DATED AT 1441 $\pm$ 23 MA (M. E. BICKFORD, U-PB). THESE SILLS ARE IN TURN CUT BY MAFIC DIKES WHICH THEMSELVES ARE INTRUDED BY PEGMATITES RELATED TO THE 1360 MA SAN ISABEL BATHOLITH. THOUGH PROTEROZOIC DIKES ARE KNOWN IN COLORADO, THESE DIKES ARE UNIQUE IN BEING PROVEN PART OF THE COLORADO ANOROGENIC SUITE.

THE GRANITIC SILLS LIE APPROXIMATELY PARALLEL TO THE FOLIATION OF AMPHIBOLITE-GRADE METAMORPHIC ROCKS OF THE WET MOUNTAINS (APPROX. 1700 MA). THE INTRUSIVES CONTAIN PHENOCRYSTS OF QUARTZ AND FELDSPAR WITH GLOMEROPORPHYRITIC CLOTS OF BIOTITE, MAGNETITE AND EPIDOTE IN A GRANITIC GROUNDMASS. CHEMICAL ANALYSES (XRF, INAA) SHOW THAT THE LIQUID WAS RHYODACITIC. TRACE ELEMENT VALUES SUPPORT A CRUSTAL ORIGIN INVOLVING SEDIMENTARY MATERIAL, THOUGH NOT SIMPLY FROM PARTIAL MELTING AT THE GRANITE MINIMA. HIGH K, HIGH FE0/FE0 + MG0, THE AGE PLACE THESE ROCKS IN THE MID-PROTEROZOIC ANOROGENIC BELT.

BASED ON CROSS-CUTTING FIELD RELATIONSHIPS, WE ALSO PROPOSE THAT THE MAFIC DIKES IN THIS VICINITY ARE A PREVIOUSLY UNRECOGNIZED PART, IN COLORADO, OF THIS ANOROGENIC BELT. THE DIKES ARE BASALTIC IN COMPOSITION WITH PRELIMINARY CHEMICAL ANALYSES SUGGESTING THEY MAY BE PART OF A PLATE-SEPARATION SUITE (AFTER HAMMOND). COMPLETE CHEMICAL ANALYSES (XRF, INAA) WILL BE AVAILABLE AT THE MEETING. THE ASSOCIATION OF THESE DIKES WITH PEGMATITES OF THE SAN ISABEL BATHOLITH MAY CONSTRAIN MODELS OF ORIGIN OF THE VERY-LOW-INITIAL SR/SR RATIOS (.7030) OF THAT BATHOLITH.

RESEARCH IN THE CLASSROOM

BY TAKING ADVANTAGE OF THE OPPORTUNITIES INHERENT IN THE BLOCK PLAN TO TAKE STUDENTS INTO THE FIELD AND THEN RETURN TO CAMPUS FOR EXTENSIVE WORK IN THE LABORATORY, WE ARE BEGINNING TO FIND WAYS IN WHICH TO ENGAGE OUR STUDENTS IN THE SCIENTIFIC ENTERPRISE EARLIER IN THEIR UNDERGRADUATE EXPERIENCE THAN THE SENIOR THESIS PERMITS.

THE CLASS WHICH HAS DONE THIS MOST SUCCESSFULLY IS COLORADO COLLEGE'S GEOMORPHOLOGY CLASS (AND A RELATED GLACIAL GEOLOGY CLASS). PROFESSOR ERIC LEONARD IS INTERESTED IN INVESTIGATING THE GLACIAL HISTORY OF SEVERAL REGIONS IN COLORADO. HIS CLASSES HAVE LEARNED TO USE TOPOGRAPHIC MAPS TO DELIMIT PLEISTOCENE SNOW LINES. THEY HAVE TRAIPSED WITH HIM TO 12,000-FEET TO EXAMINE FEATURES OF GLACIAL VALLEYS AND PRESENT-DAY ACTIVE ROCK GLACIERS. EACH CLASS ADDS TO THE DATA FROM PREVIOUS CLASSES. NEEDLESS TO SAY, PREPARATION OF GRAPHS AND FIGURES BY LARGE GROUPS HAS LED TO SOME ASTOUNDING CONCLUSIONS. THE RESULTING DISCUSSIONS OF METHODOLOGY, ERRORS, AND SCIENTIFIC PROCEDURE ARE A MAJOR FEATURE OF THE CLASS. ABSTRACTS OF TWO THESES DEVELOPED FROM THIS WORK ARE INCLUDED BELOW.

THE ACQUISITION OF FIELD EQUIPMENT THROUGH AN NSF-CSIP GRANT ENABLED A SIMILAR APPROACH TO BE UNDERTAKEN IN GEOPHYSICS. RECENT PROJECTS HAVE FOCUSSED ON USING THE GRAVITY METER AND

PROTON-PRECESSION MAGNETOMETER TO DELINEATE BASEMENT-INVOLVED FAULTS IN THE LOCAL FRONT RANGE. ONE ABSTRACT RESULTING FROM THIS WORK IS INCLUDED BELOW.

OTHER NEWER COURSES ARE IN EARLIER STAGES OF UTILIZING RESEARCH AS AN EDUCATIONAL TOOL IN THE CLASSROOM. METAMORPHIC PETROLOGY INCLUDES FIELD TRIPS WITH SMALL MAPPING PROJECTS IN THE PROFESSOR'S RESEARCH AREA. STRUCTURAL GEOLOGY HAS MAPPED SEVERAL REGIONS WHICH COULD BE USED TO ADD INSIGHT TO OUR UNDERSTANDING OF LARAMIDE STRUCTURES. IGNEOUS PETROLOGY AND VOLCANOLOGY CLASSES IN CRATERS OF THE MOON AND HAWAII, RESPECTIVELY, COULD SPAWN NUMEROUS PROJECTS.

ALTHOUGH THIS FORMAT INCLUDES AN ELEMENT OF UNCERTAINTY WHICH CAN LEAVE A CLASS FLAT WHEN NUMBERS DO NOT WORK OR MACHINES CRASH, NONETHELESS, THIS APPEARS TO BE AN EXCELLENT WAY TO INVOLVE STUDENTS IN SCIENCE EARLY IN THEIR UNDERGRADUATE EXPERIENCE.

FELSIC ROCKS OF THE CENTRAL THIRTYNINE MILE VOLCANIC FIELD

DAVID A. JOHNSON, 1988

THIS STUDY FOCUSES ON TWO GROUPS OF FELSIC ROCKS THAT OCCUR NEAR THE CENTER OF THE THIRTYNINE MILE VOLCANIC FIELD. ONE CENTER IS LOCATED IN CHUMWAY PARK AND THE OTHER IS FARTHER NORTH AT "RHYOLITE HILL" (FIG. 1). THE CHUMWAY PARK GROUP (CPG) IS COMPRISED OF VENTS AND ASSOCIATED RHYOLITE FLOWS, AND MAY REPRESENT ONE OF THE OLDEST VOLCANIC UNITS IN THE THIRTYNINE MILE VOLCANIC FIELD. A SERIES OF RHYOLITIC, PYROCLASTIC BRECCIAS IS CHEMICALLY AND SPATIALLY RELATED TO THE CPG. THE RHYOLITE HILL GROUP (RHG) IS COMPRISED OF A SHALLOW INTRUSIVE AND ASSOCIATED FELSIC FLOWS. THE ROCKS HAVE BEEN CLASSIFIED CHEMICALLY USING THE TOTAL ALKALI-SILICA DIAGRAM (TAS), RECOMMENDED BY THE IUGS (LEBAS AND OTHERS, 1986). IN CONTRAST WITH THE RHYOLITES OF THE CPG, THE FELSIC ROCKS AT RHYOLITE HILL ARE TRACHYTES AND LOW-SILICA RHYOLITES (FIG. 2), AND THE TWO GROUPS ARE CHEMICALLY QUITE DISTINCT.

THE CPG HAS A NEARLY CIRCULAR OUTCROP PATTERN, ONE-HALF MILE IN DIAMETER, AND CONSISTS OF VENT BRECCIAS, A DARK, FLOW-BANDED GLASSY RHYOLITE, PERLITES, A PINK, THINLY-LAMINATED RHYOLITE FLOW, AND A PYROCLASTIC BLOCK TEPHRA. A VENT LOCATED IN THE SOUTHERN PART OF THE GROUP (FIG. 1) HAS BEEN DELINEATED BY LARGE CLASTS OF FLOW-BANDED RHYOLITE AND PUMICE FRAGMENTS UP TO NINE CENTIMETERS IN DIAMETER. OTHER POSSIBLE SMALLER VENTS WERE MAPPED ALONG THE NORTHERN AND EASTERN EDGE OF THE BODY BY THE PRESENCE OF TUFF BRECCIAS CONTAINING CLASTS OF FLOW-BANDED RHYOLITE, AS WELL AS LARGE CLASTS (UP TO 24 CENTIMETERS ACROSS) OF PRECAMBRIAN GNEISSES WHICH DIFFER FROM THE PRECAMBRIAN BRANODIORITE FOUND LOCALLY AT THE SURFACE. THESE SMALLER VENTS SHOW INTENSE SILICIFICATION GIVING THEM A CHERTY APPEARANCE, WHICH MAY HAVE RESULTED FROM CIRCULATION OF FLUIDS WITHIN THE VENT. THE DARK, FLOW-BANDED RHYOLITE AND THE PERLITE ARE ALWAYS FOUND NEAR THE VENT LOCATIONS. THE PINK, THINLY-LAMINATED RHYOLITE FORMS THE CENTER OF THE BODY. THE PINK RHYOLITE IS YOUNGER THAN THE OTHER FLOWS BECAUSE OF THE PRESENCE OF SMALL STRINGERS OF THIS RHYOLITE CUTTING THE PERLITE BELOW. PART OF THIS UNIT IS FINE-GRAINED AND VESICULAR, PROBABLY REPRESENTING THE TOP OF A FLOW. THE WESTERN EDGE OF THE BODY IS DOMINATED BY A PYROCLASTIC BLOCK TEPHRA CONTAINING CLASTS OF FLOW-BANDED RHYOLITE, UP TO SEVEN CENTIMETERS ACROSS, REPRESENTING A SUB-AERIAL FALL DEPOSIT. TOGETHER, THE FEATURES IN CHUMWAY PARK INDICATE SURFACE EMPLACEMENT, SUGGESTING THAT WE ARE LOOKING TODAY AT THE EXHUMED TOPOGRAPHIC SURFACE WHICH EXISTED WHEN THE CPG WAS EMPLACED.

THE ROCKS OF THE CPG LIE IN CONTACT WITH ROCKS OF PRECAMBRIAN AGE (SILVER PLUME?) AND WITH THE LOWER MEMBER OF THE THIRTYNINE MILE ANDESITE (TTML) OF EPIS AND CHAPIN, 1974. IN CHUMWAY PARK, THE TTML IS SUBDIVIDED INTO THREE UNITS: A LOWER LAHARIC BRECCIA, OVERLAIN BY A BIOTITE TRACHYDACITE FLOW, PRESENT AS EROSIONAL REMANENTS OF TOPOGRAPHIC HIGHES, AND A HORNBLENDE TRACHYTE. BECAUSE OF THE LOW RELIEF AND POOR OUTCROP IN CHUMWAY PARK, ELEVATIONS AND EXTENDED DIPS WERE USED TO OBTAIN SOME OF THE WORKING STRATIGRAPHY. THE CPG CUTS AND OVERLIES THE LOWER LAHARIC BRECCIA OF THE TTML. A PERLITE PIPE IN THE HAMMOND PEAK AREA, PROBABLY REALTED TO THE CPG, ALSO CUTS THIS LOWER LAHARIC GRECCIA (PER. COMM., DAVE MOCHEL, 1988). THE FEATURES INDICATING SUBAERIAL EMPLACEMENT, AND THE TOPOGRAPHIC RELATIONS, SHOW THE CPG TO BE OLDER THAN THE OVERLYING HORNBLENDE TRACHYTE AND EITHER TO BE CONTEMPORANEOUS WITH OR OLDER THAN THE BIOTITE TRACHYDACITE. THUS, THE CPG WAS EMPLACED WITHIN THE (TTML), WHICH MAKES IT ONE OF THE OLDEST ERUPTIVE UNITS IN THE THIRTYNINE MILE VOLCANIC FIELD.

A SERIES OF GREEN, PYROCLASTIC BRECCIAS AND LAPILLI TUFFS OUTCROPS NORTH OF GUFFEY, ALONG COLORADO HIGHWAY 9 (FIG. 1), IN THE SOUTHERN DICKE PEAK AREA, AND IN THE HAMMOND PEAK AND BALDY MOUNTAIN AREAS. THE PYROCLASTIC BRECCIAS AND LAPILLI TUFFS ARE RELATED CHEMICALLY TO THE CPG AND OCCUPY THE SAME STRATIGRAPHIC POSITION. IN ADDITION, CLASTS OF FLOW-BANDED RHYOLITE SIMILAR TO THE ROCKS SEEN IN THE CPG ARE UBIQUITOUS THROUGHOUT THE BRECCIAS AND TUFFS. FINALLY, THE DECREASE IN CLAST SIZE AWAY FROM CHUMWAY PARK AND ITS CENTRAL LOCATION RELATIVE TO THE OUTCROPS OF THE TUFF BRECCIAS SUGGEST THAT CHUMWAY PARK MAY BE THEIR ERUPTIVE CENTER.

THE RHG IS SUBDIVIDED INTO TWO MAIN VOLCANIC UNITS: A RHYOLITE INTRUSION AND RELATED FLOWS, AND A SET OF TRACHYTE FLOWS. THE TRACHYTE FLOWS, OVERLYING A DIORITE

INTRUSION ON THE SOUTHEAST, A PYROXENE TRACHYANDESITE ON THE WEST AND SOUTH, AND A HORNBLENDE ANDESITE ON THE NORTH AND EAST (MAPPED AS TTML BY EPIS, 1979), COMPRISE THE LOWER PORTION OF RHYOLITE HILL. THE UPPER PORTION OF RHYOLITE HILL CONSISTS OF A SHALLOW INTRUSION OF LOW-SILICA RHYOLITE WHICH IS CAPPED BY A GLASSY, RHYOLITE FLOW.

FROM FIELD RELATIONS, THE TRACHYTE FLOWS LIE STRATIGRAPHICALLY WITHIN THE TTML. THE SHALLOW RHYOLITE AND THE ASSOCIATED RHYOLITE FLOW, OVERLIE AND CUT THE TRACHYTE FLOWS. THE INTRUSION MAY REPRESENT A SHALLOW-LEVEL MAGMA CHAMBER, WHICH SOLIDIFIED WITHIN ITS OWN EXTRUSIVE EDIFICE. THE INTRUSION HAS AREAS OF BRECCIATION WITH SECONDARY QUARTZ MINERALIZATION AND A ZONE WITH THIN, FINELY-SPACED SULPHIDE VEINS, CONTAINING PYRITE AND CHALCOPYRITE. RECONSTRUCTING THE THIRTYNINE MILE ANDESITE ALONG DIP FROM THIRTYNINE MILE MOUNTAIN TO THE NORTH, PLACES THE RHYOLITE BELOW THE MAJORITY OF THIS UNIT. THUS, THE EMPLACEMENT OF THE RHG IS CONTEMPORANEOUS WITH THE TTML.

MAJOR- AND TRACE-ELEMENT WHOLE ROCK ANALYSES DEMONSTRATE THAT THE CPG AND THE RHG ARE DISTINCTLY DIFFERENT. ADDITIONALLY, THESE DATA LINK THE PYROCLASTIC BRECCIAS AND LAPILLI TUFFS TO THE CPG. A TAS DIAGRAM, A CHONDRITE-NORMALIZED REE PLOT, AND A SERIES OF HARKER DIAGRAMS WERE USED TO EVALUATE THE DATA.

ALL OF THE ROCKS OF THE CPG ARE HIGH-SILICA RHYOLITES (FIG. 1). THEY HAVE ABOUT 4.00 WT.% NA20, ABOUT 5.00 WT.% K20, AND LOW FEO (ABOUT 1.00 WT.%) (FIG. 3). THEY ARE RELATIVELY DEPLETED IN LIL ELEMENTS, FOR INSTANCE ZN, ZR, Y, AND BA (FIG. 4). THE CPG HAS A MODEST LREE ENRICHMENT (LA/LU RATIO OF ABOUT 4.5) (FIG. 5).

IN COMPARISON TO THE ROCKS OF THE CPG, THE ROCKS OF THE RHG HAVE AN OVERALL LOWER SILICA CONTENT, BUT HIGHER TOTAL ALKALIS, AND ARE CLASSIFIED AS TRACHYTES AND LOW-SILICA RHYOLITES (FIG. 1). IN ADDITION, THE ROCKS OF THE RHG ARE RELATIVELY ENRICHED IN LIL ELEMENTS (FIG. 4). THEY ALSO HAVE ABOUT 10 TIMES THE ABUNDANCE OF REE AS THE ROCKS OF THE CPG, AND SHOW A GREATER LREE ENRICHMENT (LA/LU RATIO OF ABOUT 17) (FIG. 5).

A PETROGRAPHIC STUDY OF THE DIAGENESIS OF THE SUE POINT FOSSIL REEF SAN SALVADOR, BAHAMAS

DOUGLAS A. CATTELL, 1988

INTRODUCTION

DURING THE MONTHS OF JUNE AND JULY OF 1987 A SURVEY WAS MADE OF THE SUE POINT FOSSIL REEF ON THE NORTHWEST CORNER OF SAN SALVADOR ISLAND, BAHAMAS. CORE SAMPLES WERE TAKEN AND PETROGRAPHIC ANALYSIS OF THE SAMPLES WAS COMPLETED. THE FOLLOWING IS A DESCRIPTION OF THE FACIES DEFINED BY OUTCROP AND SAMPLE STUDY, AND A DISCUSSION OF THE DIAGENETIC SEQUENCE AND HISTORY OF THE FACIES. FIGURE 1 IS A SCHEMATIC REPRESENTATION OF THE FEATURES DESCRIBED FOR EACH FACIES.

FACIES DESCRIPTION AND INTERPRETATION

BEACH ROCK FACIES

THIS FACIES CONSISTS OF WELL WORTED AND WELL ROUNDED, CREAMY-WHITE, BIOCLASTIC LIMESTONE WITH A GRAIN SIZE VARYING FROM 1.25MM TO 3.5MM IN DIAMETER. THE ALLOCHEMS INCLUDE FORAMANIFERA; ALGAL FLAKES; AND FRAGMENTS OF CORAL, ECHINODERMS, BIVALVES AND OTHER MOLLUSCS. THIS FACIES ALSO CONTAINS PELOIDAL AND OOID GRAINS, THE LATTER OF WHICH ARE RIMMED WITH BROWN, MICRITIC, ARAGONITE CEMENT. THERE ARE ALSO INTRACLASTS COMPOSED OF TWO OR MORE OOIDS, PELOIDS, AND/OR BIOCLASTS, WITH SIMILAR CONCENTRIC ARAGONITIC RIMS THAT COAT THE ENTIRE GRAIN.

CEMENTS ARE PATCHILY DISTRIBUTED WITHIN THIS FACIES. LOW-MG CALCITE CEMENTS VARY FROM THIN RIMS ON THE SURFACES OF INDIVIDUAL GRAINS, TO VOID SPACES FULLY OCCLUDED WITH EQUANT, SPARRY CRYSTALS. THE CEMENT WITHIN THESE VOIDS EXHIBITS THE CLASSIC CORASENING-INWARD CRYSTAL SIZE PATTERN.

THIS FACIES ALSO CONTAINS INTERGRANULAR MICRITIC CEMENT COMPOSED OF LOW MG-CALCITE THAT IS LONG AND SINUOUS IN SHAPE. ASSOCIATED WITH THIS MICRITIC CEMENT ARE PATCHES OF WHISKER CALCITE. THIS TOO IS LOW-MG CALCITE, BUT IT DISPLAYS A MUCH DIFFERENT CRYSTAL HABIT OF LONG HAIR-LIKE NEEDLES RADIATING FROM A CENTRAL CORE. BOTH OF THESE CEMENT TYPES FORM AS A RESULT OF THE BIOLOGICAL ACTIVITY OF PLANTS AND FUNGI. THESE CEMENTS FORM AS SHEATHS AROUND ROOTS AND ROOT HAIRS THAT UPON ORGANIC BREAKDOWN REMAIN AS CASTS. THE WHISKER CALCITE IS A FAST GROWING CALCITE POLYMORPH ASSOCIATED WITH THE RAPID FLUX OF CO2 GAS WITHIN THE SEDIMENT RESULTING FROM THE BREAKDOWN OF THE ORGANIC ROOT MATERIAL.

CORALSTONE

THIS FACIES IS COMPOSED MAINLY OF LARGE IN SITU CORAL HEADS OF MONASTREA ANNULARIS AND ACROPORA CERVICORNIS. SOME OF THE COARLITES IN THESE HEADS ARE PARTIALLY OR COMPLETELY FILLED WITH SEDIMENTS CONSISTING OF OOIDS, PELOIDAL GRAINS, AND BIOCLASTS, AS WELL AS MICRITE AND SPARRY CALCITE CEMENT. THE BIOCLASTS IN THIS SEDIMENT INCLUDE BROKEN CORAL FRAGMENTS, BIVALVE FRAGMENTS, ANF FORAMANIFERA. THE DISTRIBUTION OF SEDIMENT INFILL IN SOME CASES DEFINES GEOPETAL STRUCTURES: EARLY MICRITIC CEMENT IS FOUND WITHIN THE SEDIMENT AND LATE-STAGE SPARRY CALCITE CEMENT IS FOUND ABOVE THE SEDIMENT IN SOME OF THE VOIDS THAT WERE PARTIALLY SEDIMENT-FILLED. THE PATCHINESS OF LATE-STAGE CEMENTATION CAN BE ATTRIBUTED TO THE IRREGULAR NATURE OF VADOSE DIAGENESIS.

EOLIANITE

THIS FACIES CONSISTS OF VERY FINE, WELL SORTED AND VERY WELL ROUNDED, LITHIFIED SAND (.0625MM - 1.25MM). THIS FACIES IS CARMEL IN COLOR, DARKER THAN THE BEACH ROCK FACIES. THE EOLIANITE IS COMPOSED OF OOIDS AND A MINOR AMOUNT OF BIOCLASTS THAT INCLUDE BIVALVE FRAGMENTS, ALGAL FLAKES, FORAMANIFERA, AND CORAL FRAGMENTS. THIS FACIES IS COMPOSED OF A SERIES OF NORMALLY GRADED LAMINAE 0.2MM TO 0.5MM THICK. NORMAL GRADING IS COMMON IN EOLIAN DEPOSITS AND FORMS DURING PROGRADATION OF DUNES.

THE EOLIANITE FACIES IS GENERALLY WELL CEMENTED. SOME WHISKER CALCITE IS PRESENT BUT THE MAJORITY OF THE CEMENT IS EQUANT, SPARRY, LOW-MG CALCITE. THERE IS AN INVERSE RELATIONSHIP BETWEEN THE SIZE OF THE GRAINS AND THE DEGREE AND STYLE OF CEMENTATION WITHIN THE LAMINAE. THE LAMINAE COMPOSED OF LARGE GRAINS EXHIBIT MORE RIM CEMENTS AND LESS PORE-FILLING CEMENTATION THAN THE LAMINAE OF SMALLER GRAIN SIZE WHICH ARE GENER-

ALLY FILLED WITH EQUANT CRYSTALS. THIS DISTRIBUTION IS A FUNCTION OF THE CAPILLARY ACTION WITHIN THE SEDIMENTS AT THE TIME OF CEMENTATION. SMALLER GRAINS OF CEMENT TENDS THEREFORE TO BE MORE COMPLETE WITHIN FINER SANDS, WHEREAS LARGER GRAINS WHICH ARE USUALLY COVERED BY THIN FILMS OF WATER, TEND TO BE SURROUNDED WITH RIM CEMENTS.

SUBTIDAL CALCARENITE

THIS FACIES CONSISTS OF POORLY SORTED, WELL ROUNDED, CALCARENITE. THE SEDIMENT RANGES FROM VERY FINE TO MEDIUM SAND SIZE (.0625MM TO 3.0MM). THE SEDIMENT IS BIOCLASTIC WITH MINOR AMOUNTS OF PELOIDAL AND OOLITIC GRAINS. THE BIOCLASTS INCLUDE ALGAL FLAKES, MOLLUSC FRAGMENTS, CORAL FRAGMENTS, FORAMINIFERA, AND ECHINODERM FRAGMENTS.

THE TOTAL VOLUME OF CEMENT IS MINOR AND THERE ARE TWO GENERAL TYPES: INTRAGRANULAR AND INTERGRANULAR. THE INTRAGRANULAR CEMENT CONSISTS OF FIBROUS AND DOGTOOTH ARAGONITE. THESE CEMENTS ARE FOUND WITHIN: (1) PORES OF ALGAL FLAKES, (2) THE CHAMBERS OF FORAMANIFERA TESTS, AND (3) SECONDARY VOIDS WITHIN OOIDS AND OTHER ALLOCHEMS. SMALL AMOUNTS OF WHISKER CALCITE CAN ALSO BE FOUND IN THESE VOID SPACES.

THE INTERGRANULAR CEMENT IS FOUND IN SEVERAL FORMS. BROWN, BLOTCHY, MARINE MICRITE CEMENT IS PATCHILY DISTRIBUTED HOLDING SMALL GROUPS OF OOIDS AND BIOCLASTS TOGETHER. LAMINAR, ORANGE-BROWN MICRITIC ARAGONITE CEMENT ALSO RIMS INTRACLASTS THAT WERE MOST LIKELY DERIVED FROM BEACH ROCK OR HARDGROUNDS. THESE INTRACLASTS EXHIBIT TWO GENERATIONS OF CEMENTATION: BOTH THE COMPONENT GRAINS AND THE INTRACLASTS THEMSELVES ARE RIMMED WITH THIS LAMINAR MICRITIC MARINE CEMENT (ARAGONITE OR HIGH-MG CALCITE). THERE ARE ALSO MENISCUS CEMENTS COMPOSED OF LOW-MG CALCITE, THAT EXHIBIT SMOOTH CURVILINER CRYSTAL FACES. THE CURVILINEAR NATURE IS APPARENTLY CAUSED BY PRECIPIATION OF CALCITE AROUND BUBBLES AT THE WATER-AIR INTERFACE. WHISKER CALCITE IS ALSO PRESENT IN SMALL AMOUNTS WITHIN VOID SPACES IN THE SEDIMENT.

DISCUSSION

THE ABOVE DISCUSSION OF FACIES HAS FOCUSSED ON THE COMPOSITIONAL AND TEXTURAL NATURE OF ALLOCHEMS AND CEMENTS. BASED ON THE RELATIONSHIP BETWEEN ALOCHEMS AND CEMENTS AND BETWEEN VARIOUS CEMENT TYPES, A SEDIMENTOLOGIC AND DIAGENETIC HISTORY WILL BE OUTLINED BELOW.

THE EARLY STAGES OF DEPOSITION INVOLVED THE FORMATION OF WELL WASHED BIOCLASTIC AND OOLITIC SEDIMENT. AT THIS TIME MARINE ARAGONITIC CEMENTS WERE PRECIPITATED AROUND OOID GRAINS AND TO A LESSER EXTENT BETWEEN VARIOUS ALLOCHEMS. EROSION AND TRANSPORT OF EARLY-CEMENTED SEDIMENT FROM LOCALLY DEVELOPED HARDGROUNDS AND BEACHROCK CREATED INTRACLASTS WHICH WERE IN TURN SUBJECTED TO ARAGONITIC RIM CEMENTATION DURING TRANSPORT. AFTER FINAL DEPOSITION THE INTRAGRANULAR SPECES OF SOME BIOCLASTS WERE SITES OF PRECIPITATION OF FIBROUS ARAGONITE. THIS FIBROUS ARAGONITE FORMED IN THE MARINE PHREATIC ZONE AND MARKED THE END OF THE DIAGENETIC PHASE OF THESE SEDIMENTS, AT WHICH POINT THERE WAS LITTLE INTERGRANULAR CEMENT. AN EXCEPTION TO THIS IS THE EARLY MICRITIC CEMENT WITHIN THE SEDIMENT FORMING THE GEOPETAL STRUCTURES IN THE VOID SPACES OF THE CORALSTONE.

THE SEDIMENTS OF THIS STUDY ARE PRESENTLY IN THE METEORIC VADOSE ZONE, WHICH, CONSIDERING THAT THE HOLOCENE HAS BEEN A PERIOD OF EUSTATIC SEA LEVEL RISE, INDICATES PROLONGED EXPOSURE OF THESE SEDIMENTS TO METEORIC WATERS. THERE IS, IN FACT, CONSIDERABLE EVIDENCE FOR A SECOND DIAGENETIC PHASE OF ALTERATION AND CEMENTATION UNDER METEORIC VADOSE CONDITIONS. THE DOMINANT INTERGRANULAR CEMENT CONSISTS OF EQUANT, SPARRY LOW-MG CALCITE WITH VARIOUS TEXTURES DIAGNOSTIC OF VADOSE CONDITIONS (E.G. RIM, PENDANT, MENISCUS, AND WHISKER CALCITE CEMENTS). THE DISSOLUTION OF OOID CORES AND THE PRECIPITATION OF LOW-MG CALCITE, BLOCKY CEMENTS ALSO OCCURED AT THIS TIME. THE PROLONGED EXPOSURE OF THESE FACIES TO METEORIC WATERS HAS CAUSED LOCAL DEVELOPMENT OF THIN, DRAPED CALICHE LAYERS AND THE LONG SINUOS LOW-MG CALCITE CEMENT THAT FORMED AROUND ROOTS AND ROOT HAIRS.

SENIOR THESES AND RELATED PROJECTS

ALL COLORADO COLLEGE GEOLOGY MAJORS ARE REQUIRED TO COMPLETE A SENIOR THESES, INCLUDING A PROFESSIONAL-MEETING STYLE ORAL PRESENTATION. STUDENTS ARE STRONGLY ENCOURAGED TO UNDERTAKE ORIGINAL RESEARCH FOR THEIR THESES, THOUGH A VARIETY OF FORMATS IS ACCEPTABLE. STUDENTS WHOSE RESEARCH MEETS ADDITIONAL REQUIREMENTS MAY BE AWARDED HONORS. MOST STUDENTS TAKE ADVANTAGE OF THE BLOCK PLAN TO BEGIN THEIR RESEARCH; A NUMBER OF THESE HAVE DEVELOPED OUT OF CLASSROOM PROJECTS.

INCLUDED BELOW ARE A VARIETY OF ABSTRACTS RANGING FROM SIMS' WORK ON INCLUSION (PRESENTED AT AGU) THROUGH THE WORK OF SEVERAL STUDENTS WHO WENT TO COSTA RICA ON THE ASSOCIATED COLLEGES OF THE MIDWEST SPRING SEMESTER PROGRAM, TO A LOCAL FAULT ANALYSIS AT THE GARDEN OF THE GODS.

GRAVITY DATA INVERSION: AN EXAMPLE FROM SOUTH PARK, COLORADO

ROBERT D. VINCENT, 1988

IN MAY, 1987, GARY GEIST AND PROFESSOR RICHARD HILT CARRIED OUT A GRAVITY SURVEY ALONG HIGHWAY 24 IN SOUTH PARK, BETWEEN WILKERSON PASS AND THE TOWN OF HARTSEL. THE ELEVATION AND RELATIVE ACCELERATION OF GRAVITY WERE RECORDED FOR EACH OF 62 STATIONS SPACED 1200 FEET APART ALONG THE HIGHWAY. THE SUBSEQUENT INTERPRETATION OF THE DATA WAS LIMITED TO RELATIVELY SIMPLE MODELING TECHNIQUES, AND LITTLE COMPARISON WITH THE RESULTS OF OTHER STUDIES WAS ATTEMPTED. THIS WORK HOPEFULLY PRESENTS A MORE THOROUGH EVALUATION OF THE DATA OBTAINED FROM THE SURVEY, USING A MORE REALISTIC MODELLING TECHNIQUE.

NEW GRAVITY MEASUREMENTS WERE TAKEN AT A BENCHMARK EAST OF THE SUMMIT OF WILKERSON PASS IN ORDER TO ESTABLISH AN ABSOLUTE VALUE FOR THE ANOMALY RESULTING FROM THE SEDIMENTS PRESENT IN SOUTH PARK. WITHOUT THIS INFORMATION IT WOULD HAVE BEEN IMPOSSIBLE TO ESTIMATE THE ACTUAL THICKNESS OF THE SEDIMENTS.

THE STRUCTURE UNDERLYING THE SURVEY LINE WAS MODELED AS A SEQUENCE OF SLABS OF FINITE DEPTH AND WIDTH BUT WITH INFINITE EXTENT PERPENDICULAR TO THE SURVEY LINE. THE SLABS, WHICH REPRESENT THE MESOZOIC AND CENOZOIC SEDIMENTS, ARE ASSUMED TO HAVE A DENSITY CONTRACT (P) OF -.25 G/CM^3 (SABET, 1966) RELATIVE TO THE PRECAMBRIAN CRYSTALLINE ROCKS.

FOR EACH DATA POINT, THE GRAVITY FIELD OF EVERY SLAB WAS SUMMED TO GENERATE AN ESTIMATED VALUE FOR THE GRAVITY ANOMALY. AN ITERATIVE ALGORITHM WAS USED WHICH CALCULATED THE PREDICTED VALUES OF THE ANOMALY BASED ON THE CURRENT SET OF SLAB DEPTHS, THEN CORRECTED THE MODEL TO REDUCE THE DISAGREEMENT BETWEEN THE PREDICTED AND OBSERVED GRAVITY ANOMALIES. THIS PROCESS WAS REPEATED UNTIL THE ERROR IN THE MODEL WAS MINIMIZED.

MODELS WERE GENERATED FOR THE "EVEN-DETERMINED" CASE, IN WHICH THERE ARE ASSUMED TO BE AS MANY SLABS (62) AS THERE ARE DATA POINTS, AS WELL AS FOR TWO DIFFERENT "OVER-DETERMINED" CASES, USING 31 AND 15 SLABS. TO EVALUATE THE RELIABILITY OF THESE MODELS AND THE SENSITIVITY OF THE INVERSION ALGORITHM, ADDITIONAL MODELS WERE GENERATED USING "DOCTORED" DATA TO WHICH PSEUDOGAUSSIAN NOISE WITH VARIANCE =1.0 MILLIGAL WAS ADDED. THE RESULTS OF THESE TESTS SUGGEST THAT THE OVER-DETERMINED MODELS ARE MUCH MORE STABLE THAN THE EVEN-DETERMINED MODEL.

THE FINAL MODEL WAS COMPARED TO THE RESULTS OF EARLIER RESEARCH, ESPECIALLY THE GRAVITY SURVEY OF SNYDER (1968) AND THE SEISMIC WORK OF DURRANI (1980). THE MODEL FAVORS THE INTERPRETATION OF THE ELKHORN FAULT AS A LOW-ANGLE THRUST FAULT, AS SUGGESTED BY SNYDER.

PALEOCLIMATOLOGY OF FOURMILE CREEK VALLEY

ALAN MANLEY, 1986

GEOMORPHOLOGICAL EXAMINATION OF FOURMILE CREEK GULCH IN THE MOSQUITO RANGE OF COLORADO INDICATED CONSIDERABLE QUATERNARY GLACIAL ACTIVITY. THIS STUDY ENTAILED MAPPING ANY QUATERNARY DEPOSITS FOUND, DATING THESE DEPOSITS BY THE USE OF GRAIN SIZE AND CARBONATE ANALYSIS, TO CALCULATE THE MASS DYNAMICS OF THE PALEOGLACIERS, AND TO MAKE SOME CLIMATIC INFERENCES FROM THIS DATA. THIS STUDY ALSO ATTEMPTS TO ACCURATELY COMPARE THIS AREA TO OTHER SIMILAR STUDIES DONE IN COLORADO AND WYOMING. AFTER FIELD STUDY OF FOURMILE CREEK GULCH WEST OF FAIRPLAY, COLORADO, THE PALEOGLACIERS WERE RECONSTRUCTED (AFTER ANDREWS, 1975, AND PATERSON, 1982). AFTER RECONSTRUCTION, THE VELOCITIES, MASS FLUXES, ABLATION GRADIENTS AND ACTIVITY INDEXES WERE DETERMINED AND COMPARED TO MODERN GLACIERS. BY NOTING THE CLIMATE IN WHICH THE MODERN GLACIERS EXIST, AND ASSUMING THAT THE MODERN AND PALEOGLACIERS BEHAVE SIMILARLY IN SIMILAR CLIMATES, ONE CAN INFRE THE PALEOCLIMATE THAT A GIVEN PALEOGLACIER MUST HAVE EXISTED IN. GRAIN SIZE AND CARBONATE CONTENT WERE ANALYZED IN THE LABORATORY, AND THE RESULTS WERE COMPARED TO SOILS OF KNOWN AGES (BY RADIOMETRIC DATING PROCESSES) TO DETERMINE AN APPROXIMATE AGE.

PALEOFLOOD RECONSTRUCTION: ARKANSAS RIVER VALLEY

BRIAN LINK, 1988

SOUTH OF LEADVILLE, COLORADO, THE ARKANSAS RIVER RUNS THROUGH A DOWNDROPPED VALLEY BOUNDED BY THE SAWATCH RANGE ON THE WEST AND THE MOSQUITO RANGE ON THE EAST. SEVERAL TIMES DURING THE PLEISTOCENE, THE PINE CREEK VALLEY (A SMALL VALLEY PERPENDICULAR TO THE ARKANSAS VALLEY) WAS OCCUPIED BY A GLACIER. DURING SOME OF THESE OCCUPATIONS, THE ICE FLOWED ACROSS THE MAIN VALLEY FLOOR, DAMMING THE ARKANSAS RIVER AND FORMING A LAKE. THE LAKES MAY HAVE BEEN AS DEEP AS 200 METERS. SOME OR ALL OF THESE LAKES DRAINED CATASTROPHICALLY, RESULTING IN EXTENSIVE FLOODING OF THE ARKANSAS VALLEY.

PALEOFLOW PARAMETERS OF AVERAGE VELOCITY, DEPTH OF FLOW, AND DISCHARGE RATES OF ONE SUCH FLOOD WERE ESTIMATED USING A VARIETY OF THEORETICAL TECHNIQUES, BASED ON FIELD DATA. MEASUREMENT OF BOULDER SIZE (INTERMEDIATE DIAMETER) ALLOWED CALCULATION OF AVERAGE VELOCITY USING AN EQUATION DEVELOPED BY COSTA (1983). CALCULATION OF VELOCITY ALLOWED DETERMINATION OF DEPTH USING THE MANNING EQUATION WHICH RELATES SLOPE (S) AND DEPTH (R) TO VELOCITY (V):

$$V=\frac{S^{0.5}}{N}R^{0.66}$$

MANNING'S N (A SCALE OF BED ROUGHNESS) WAS HELD CONSTANT AT 0.025, BUT THIS DOES NOT FIGURE TO BE A SOURCE OF CONSIDERABLE ERROR. SLOPE WAS DETERMINED BY CONSTRUCTION OF CORSS SECTIONS FROM TOPOGRAPHIC MAPS. CHANNEL WIDTH WAS ALSO DETERMINED FROM TOPOGRAPHIC MAPS, AND WAS COMBINED WITH VELOCITY AND DEPTH VALUES TO ESTIMATE DISCHARGE.

BOULDER SIZE DISTRIBUTION SHOWS A PATTERN OF ACCELERATION AND DECELERATION OF THE FLOOD DUE TO CHANNEL CONSTRICTION. ESTIMATES OF AVERAGE VELOCITY SUGGEST THAT THE FLOOD REACHED SPEEDS OF 12 M/S, AND FLOW DEPTHS OF 5.7 METERS. DISCHARGE ESTIMATES WERE NOT ACCURATE ENOUGH TO BE CONSIDERED AS ABSOLUTE VALUES.

A MICROFAULT ANALYSIS OF THE PERIAN LYONS SANDSTONE AT THE GARDEN OF THE GODS COLORADO SPRINGS, COLORADO

LOWE BILLINGSLEY, 1988

THE ROCKY MOUNTAIN FRONT IS BOUNDED BY LARAMIDE AGE (65 M.Y.) THRUST FAULTS AND HIGH ANGLE REVERSE FAULTS THAT ARE THE RESULT OF PRECAMBRIAN CRYSTALLINE BASEMENT UPLIFTS AND EAST-WEST REGIONAL COMPRESSION. THE FLANKS OF THE FRONT ARE CHARACTERIZED BY NEAR VERTICAL STRATA THAT FORM FAULT-RELATED FLEXURES OF THE SEDIMENTARY COVER. THE RELATION BETWEEN FAULTING, REGIONAL STRESSES, AND THE RESULTING STRUCTURES IS THE DISTINGUISHING TRAIT OF THE LARAMIDE OROGENY. THE GARDEN OF THE GODS IS ONE LOCALITY ALONG THE FRONT RANGE WHERE LARAMIDE FEATURES ARE ACCESSIBLE FOR STUDY. IN PARTICULAR, THIS DEFORMATION IS EXPRESSED IN THE PERMIAN LYONS SANDSTONE AT THE GARDEN OF THE GODS AS NUMEROUS MICRO- AND MACROFAULTS. I MEASURED SEVERAL HUNDRED FAULTS WITHIN THE LYONS SANDSTONE IN ORDER TO RELATE THEM TO REGIONAL AND LOCAL TECTONICS, AND TO SEE IF THE MICRO- AND MACROFAULTS ARE GENETICALLY RELATED.

THE GARDEN OF THE GODS CONSISTS OF PENNSYLVANIAN THROUGH LATE CRETACEOUS AGE STRATA. DEFORMATION HAS ROTATED BEDDING IN ALL OF THE UNITS TO NEAR VERTICAL. THE UNITS STRIKE APPROXIMATELY DUE NORTH PARALLELING THE RAMPART RANGE FAULT TO THE WEST. THIS FAULT IS A WEST DIPPING REVERSE FAULT TRACEABLE AT THE SURFACE FROM JUST SOUTH OF THE GARDEN OF THE GODS NORTHWARD FOR 65 KM. IN ADDITION, SEVERAL EAST DIPPING REVERSE FAULTS WITHIN THE STUDY AREA HAVE OFFSET INDIVIDUAL UNITS ACROSS STRIKE.

WITHIN THE LYONS SANDSTONE MY ANALYSIS SHOWS TWO PRINCIPAL ORIENTATIONS OF MICROFAULTS WITH REVERSE SENSE AT N45E, 45SE AND N34W, 38SW. INTERPRETATION SHOWS THAT THESE FAULTS FORMED AS A REVERSE CONJUGATE SET WITH "SIGMA$_1$" HORIZONTAL AND EAST-WEST. THE ORIENTATION OF THE PRINCIPAL STRESSES "SIGMA$_1$", "SIGMA$_2$", AND "SIGMA$_3$" ARE 4, S81E; 31, S12W; AND 60, N1E. THE 62^0 ANGLE SEPARATING THE CONJUGATE FAULTS ACCORDS WITH LABORATORY EXPERIMENTS ON SIMILAR ROCKS. AN EXAMPLE IS THE WIND RIVER THRUST FAULT IN WYOMING THAT HAS AN ANGLE OF SEPARATION OF 70^0. FIELD ANALYSIS OF THE LYONS SHOWS THAT THE MICROFAULTS HAVE NOT BEEN ROTATED SINCE THEIR GENESIS.

FROM FIELD OBSERVATIONS, THE EAST DIPPING MACROFAULTS DIP 40-65^0. THE MAGNITUDE OF DIP ON THE RAMPART RANGE FAULT IS HOTLY DEBATED BY SPECIALISTS, BUT IS GENERALLY AGREED TO BE WEST DIPPING. THESE ORIENTATIONS FOR THE LARGER FAULTS FORM A REVERSE CONJUGATE SET, ALSO WITH "SIGMA$_1$" HORIZONTAL AND EAST-WEST.

INTERPRETATION OF THESE FINDINGS SHOWS THAT THE MICROFAULTS WITHIN THE LYONS SANDSTONE AND THE MACROFAULTS OF THE REGION ARE GENETICALLY RELATED. THE MICROFAULTS WITHIN THE PERMIAN LYONS SANDSTONE AT THE GARDEN OF THE GODS AND THE REGIONAL MACROFAULTS ARE SYNCHRONOUS AND SYNTECTONIC TO EACH OTHER AND ALSO TO THE LARAMIDE OROGENY.

INCLUSIONS IN THE TSCHICOMA FORMATION

KEN SIMS, 1986

THE TSCHICOMA FORMATION OF THE POLVADERA GROUP IN THE JEMEZ VOLCANIC FIELD HAS TWO MEMBERS: A TWO-PYROXENE ANDESITE AND A HORNBLENDE-BEARING DACITE/RHYODACITE. THIS LATTER ROCK CONTAINS UBIQUITOUS INCLUSIONS OF BASALTIC ANDESITE, CONSISTING OF ACICULAR OXY-HORNBLENDE (SOMETIMES REPLACING PYROXENE), CA-PLAGIOCLASE (AN60), GLASS (10%), AND VESICLES (20-25%). THESE INCLUSIONS MAKE UP BETWEEN 0-8 VOLUME PERCENT OF THE TSCHICOMA DACITE.

INCLUSIONS IN VOLCANIC ROCKS HAVE BEEN VARIOUSLY INTERPRETED AS: 1) REFRACTORY RESIDUUM (RESTITES) FROM A PARTIALLY MELTED SOURCE, 2) ACCIDENTAL XENOLITHS, 3) MINERAL CLOTS PRODUCED BY FRACTIONAL CRYSTALLIZATION, AND 4) THE PRODUCT OF MAGMA MIXING.

THE TEXTURE, MINERALOGY AND GEOCHEMISTRY OF THE INCLUSIONS IN THE TSCHICOMA FORMATION WERE EXAMINED AND THEN COMPARED WITH THE CHARACTERISTIC FEATURES EXPECTED FOR EACH OF THESE FOUR MODELS. ON THIS BASIS, IT WAS DETERMINED THAT THESE INCLUSIONS ARE A RESULT OF MAGMA MIXING AT AN UNSTABLE INTERFACE BETWEEN THE TSCHICOMA DACITE AND A MANTLE-DERIVED BASALT INJECTED AT ITS BASE.

TEXTURALLY, THE INCLUSIONS SHOW CHILLING AGAINST THE LOWER-TEMPERATURE HOST. AVERAGE GRAIN SIZE IN THE INCLUSIONS DECREASES TOWARD THE BORDER, AND HORNBLENDE AND PLAGIOCLASE CHANGE FROM SUBEQUANT TO HIGHLY ELONGATE. THE PHENOCRYSTS IN THE HOST LAVA ARE REACTED OR RESORBED CONSISTENT WITH THE HEATING OF THE RESERVOIR MAGMA DURING COOLING AND CRYSTALLIZATION OF THE INCLUSIONS. FINALLY, PHENOCRYSTS AND COGNATE CLOTS FROM THE HOST TSCHICOMA WERE FOUND <u>WITHIN</u> THE INCLUSIONS. THIS TEXTURAL DATA INDICATES THAT BOTH HOST AND INCLUSION WERE LIQUID AT THE SAME TIME.

MAJOR, TRACE, AND RARE-EARTH ELEMENT CONCENTRATIONS OF THE INCLUSIONS (57 WT% SiO_2) ARE ALL INTERMEDIATE BETWEEN THOSE OF THE HOST TSCHICOMA DACITE (68 WT% SiO_2) AND AN ASSOCIATED MAFIC LAVA, THE LOBATO BASALT (49 WT% SiO_2). IN FACT, THE INCLUSIONS' MAJOR, TRACE AND RARE-EARTH ELEMENT CONCENTRATIONS CAN BE MODELLED BY MIXING .54 LOBATO BASALT AND .46 TSCHICOMA DACITE.

THIS EVIDENCE FOR MAGMA MIXING IN THE JEMEZ VOLCANIC FIELD CONTRIBUTES TO THE RECENT HYPOTHESIS OF LOEFFLER (1984) AND GARDNER AND GOFF (1984): WHO SUGGEST MAGMA MIXING IS A RESULT OF THE TECTONIC "LULL" (WHICH BEGAN ABOUT 7 M.Y. AGO) IN THE ACTIVITY OF THE RIO GRANDE RIFT. THIS REDUCED EXTENSION AND EFFUSION OF LAVAS AT THE SURFACE IS THOUGHT TO PLAY A DOMINANT ROLE IN THE FORMATION OF HYBRID MAGMAS AT DEPTH.

GEOLOGY OF ISLA DE CANO, COSTA RICA

ROLFE SPIEGEL, 1988

SEVERAL HUNDRED FAULTS, JOINTS, AND JOINT SETS WERE MEASURED ON ISLA DEL CANO TO DETERMINE CONCENTRATIONS OF STRUCTURES AND THE ORIENTATIONS OF PRINCIPAL STRESS THAT CAUSED THESE STRUCTURES. THROUGH THIS ANALYSIS A BETTER MODEL HAS BEEN FORMED OF SUBDUCTION LOCAL TO ISLA DEL CANO, AND THE EFFECT THE SUBMERGED COCOS RIDGE HAS ON THE SUBDUCTION ZONE. ISLA DEL CANO IS A SMALL ISLAND (3 KM. LONG BY 2 KM. WIDE) LOCATED OFF THE SOUTHWEST COAST OF COSTA RICA. IT LIES JUST SHOREWARD OF THE CENTRAL AMERICAN TRENCH (CAT) WHICH IS CAUSED BY SUBDUCTION OF THE NE MOVING COCOS PLATE UNDER THE E MOVING CARIBBEAN PLATE. HOT SPOT VOLCANISM LOCATED IN AND NEAR THE GALAPAGOS ISLANDS HAS CREATED AN UNDERWATER RIDGE PARALLELING PLATE MOVEMENT AS THE COCOS PLATE HAS MOVED OVER THE HOT SPOT. THE LEADING EDGE OF THIS RIDGE RECENTLY REACHED THE CAT, AND HAS BEEN PARTIALLY SUBDUCTED. THE RELATIVE BOUYANCY OF THE RIDGE HAS HALTED SUBDUCTION (BASED ON LACK OF LOCAL SEISMIC ACTIVITY), AND HAS CREATED A STRESS FIELD WHICH DIFFERS FROM THAT IN THE SURROUNDING TRENCH.

THIS STUDY WAS THE FIRST STRUCTURAL WORK DONE ON THE ISLAND AND ALL FURTHER INTERPRETATIONS ARE BASED ON THE AUTHOR'S DATA. IN OUTCROPS THROUGHOUT THE ISLAND A GENERAL, FAIRLY CONSISTENT SERIES OF DEFORMATIONAL PERIODS CAN BE SEEN. DEPOSITION OF BEDDED SEDIMENTS (S0) WAS FOLLOWED BY FAULTING AND BOUNDINAGE (D1) WITHIN THE PLANE OF BEDDING AND TILTING OF BEDDING; SMALL SCALE FOLDING (D2); FAULTING (D3); AND SOME FURTHER FAULTING OF S3, HOWEVER, D3 AND LATER FAULTING CANNOT BE DIFFERENTIATED INTO SEPARATE PERIODS.

EXPECTED AND OBSERVED MEASUREMENTS OF STRUCTURES IN THE ISLAND CORRELATE TO VARYING DEGREES BUT THE OBSERVATIONS FIT FAIRLY WELL WITH A MODEL OF NORMAL SUBDUCTION FOLLOWED BY TRENCH BLOCKAGE, UPLIFT, AND SECONDARY DEFORMATION ASSOCIATED WITH RIDGE SUBDUCTION. BEDDING AND LARGE SCALE FAULTS PRIMARILY DIP TO THE NE, AS EXPECTED FOR ACCRETION WITH SHEAR PARALLEL TO THE NE DIPPING SUBDUCTION ZONE. TWO CONCENTRATIONS OF SMALL SCALE FAULTS/JOINTS, ONE NNE DIPPING, AND ANOTHER ENE DIPPING OCCUR IN CONJUGATE SHEAR ORIENTATIONS, WHILE ANOTHER NW DIPPING CONCENTRATION IS ORIENTED SIMILARLY TO THE LARGE SCALE FAULTS. THESE FRACTURES ARE INTERPRETED TO BE THE RESULT OF NW DIRECTED HORIZONTAL FRICTIONAL STRESSES GENERATED PARALLEL TO THE SUBDUCTION ZONE AS THE RIDGE PASSES OBLIQUELY BENEATH THE OVERRIDING PLATE. A VERTICAL NE STRIKING JOINT SET CORRESPONDS TO TENSILE FRACTURES CAUSED BY NORMAL NE DIRECTED COMPRESSION GENERATED BETWEEN THE CONVERGING PLATES. THIS STRESS FIELD ALSO CAUSED TWO MORE VERTICAL CONJUGATE SETS, ONE STRIKING ENE AND THE OTHER NNE. THE MODEL PRESENTED HERE IS NOT PERFECT, BUT IS THE SIMPLEST EVOLUTIONARY MODEL THAT ACCOUNTS FOR ALL THE MAJOR STRAIN ORIENTATIONS. PERHAPS IF ABSOLUTE AGES COULD BE DETERMINED FOR THE RELATIVE DEFORMATIONAL PERIODS A MORE DEFINITE HISTORY FOR THE AREA COULD BE GIVEN.

LOCAL AND REGIONAL ASPECTS OF STRUCTURAL GEOLOGY
PUNTA JUDAS, COSTA RICA

DOUG HALLER, 1988

PUNTA JUDAS, IN THE PROVIDENCE OF PUNTARENAS, COSTA RICA WAS THE SITE OF A RECENT STUDY IN STRUCTURAL GEOLOGY. SEVERAL HUNDRED MEASUREMENTS OF BEDS, FAULTS AND JOINTS WERE TAKEN AT THE OUTCROP TO DETERMINE THE ORIENTATIONS OF PRIMARY STRESSES RESULTING IN THE LOCAL DEFORMATION. ANALYSIS OF THE DATA HAS SHED LIGHT ON THE LOCAL AND REGIONAL INFLUENCES ON DEFORMATION AT THE LOCATION.

IN ORDER TO UNDERSTAND THE LOCAL DEFORMATION AT PUNTA JUDAS ONE MUST UNDERSTAND SOMETHING OF THE REGIONAL STRUCTURAL TRENDS. THE COSTA RICAN LANDMASS REPRESENTS PART OF AN INTRA-OCEANIC ARC COMMONLY FOUND ALONG SUBDUCTION ZONES. THE PRESENT DAY LAND BRIDGE HAS BEEN RECENTLY UPLIFTED AS A RESULT OF THE COLLISION BETWEEN AND SUBSEQUENT SUBDUCTION OF THE COCOS PLATE BENEATH THE CARIBBEAN PLATE. AS A RESULT OF THIS COLLISION, PRIMARY GEOLOGICAL STRUCTURES ARE ORIENTED NW TO SE THROUGHOUT THE REGION, AS EXEMPLIFIED BY LARGE SCALE FAULTS AND OROGENIC BELTS. IN ADDITION, RECENT TECTONIC ACTIVITY AND DROPS IN SEA LEVEL HAVE RESULTED IN THE SURFACING OF SMALL MARINE BASINS. PUNTA JUDAS, A MID-MIOCENE SEDIMENTARY SEQUENCE REPRESENTATIVE OF AN ESTUARINE ENVIRONMENT, EXEMPLIFIES THESE ACTIVITIES.

STRUCTURAL GEOLOGY AT PUNTA JUDAS IS RELATED TO BOTH LOCAL AND REGIONAL STRESSES. ROSE DIAGRAMS FOR FAULTS AND JOINTS SHOW OVERLAPPING MAXIMA. THE TWO MAXIMA FOR FAULTS ARE $N10^{O}$ TO $30^{O}W$ AND $N30^{O}$ TO $50^{O}E$. SIMILARLY, TWO MAXIMA FOR JOINTS ARE $N20^{O}$ TO $40^{O}W$ AND $N40^{O}$ TO $50^{O}E$. A THIRD JOINT MAXIMUM AT $N80^{O}$ TO $90^{O}E$ DOES NOT APPEAR TO BE RELATED TO FAULTING. 146 POLES TO FAULTS WERE PLOTTED ON A LOWER HEMISPHERE STEREONET. TWO MAXIMA WERE REVELED THROUGH THIS PLOT: $N21^{O}W$, $50^{O}SW$ AND $N40^{O}E$, 30^{O} TO $50^{O}W$. A STEREONET PLOT OF THE PLANES TO THE MAXIMA SHOWS THAT 42^{O} EXISTS BETWEEN THE TWO CONCENTRATIONS. WHILE THE ANGLE BETWEEN THE PLANES IS NOT 60^{O}, DUE TO THE ROCKS SEDIMENTARY NATURE THE FAULT PLANES CAN BE CONSIDERED TO BE CONJUGATE. PRINCIPAL STRESSES WERE FOUND TO BE SIGMA ONE AT 10^{O}, $S19^{O}W$; SIGMA TWO AT 42^{O}, $N63^{O}W$; AND SIGMA THREE AT 48^{O}, $S81^{O}E$. IT IS BELIEVED THAT THE COCOS PLATE IS SUBDUCTING AT BETWEEN $N7^{O}$ AND $10^{O}E$ AT RATE OF SEVEN TO NINE CENTIMETERS ANNUALLY IN THIS REGION. THUS, SIGMA ONE IS ORIENTED NEARLY PARALLEL TO THE DIRECTION OF PLATE CONVERGENCE. THE TEN DEGREE PLUNGE OF SIGMA ONE IS RELATED TO REGIONAL UPLIFT.

IN CONTRAST, THE DEFORMATION OF BEDS CANNOT BE RELATED TO REGIONAL STRESS PATTERNS. A STEREONET PLOT OF 221 POLES TO BEDDING SHOWS THAT THE MAJORITY OF THE BEDS ARE ORIENTED $N17^{O}E$, $33^{O}E$. THIS ORIENTATION IS ROUGHLY PARALLEL TO THE DIRECTION OF PRINCIPAL STRESS AND THE DIRECTION OF SUBDUCTION. THE AXIS ORIENTATION OF GENTLE FOLDS CANNOT BE EXPLAINED BY REGIONAL STRESS. THEREFORE, THESE FINDINGS SUGGEST THAT LOCAL STRESSES ARE RESPONSIBLE FOR BED DEFORMATION.

THE DISTRIBUTION OF COARSE-GRAINED SEDIMENTS IN MODERN LAKE TURKANA, KENYA: IMPLICATIONS FOR CLASTIC SEDIMENTATION MODELS OF RIFT LAKES

A. S. COHEN, D. S. FERGUSON, P. M. GRAM, S. L. HUBLER AND K. W. SIMS

SUMMARY: THE NEARSHORE ENVIRONMENT OF LAKE TURKANA, KENYA WAS STUDIED TO DETERMINE HOW COARSE CLASTIC SEDIMENTS ARE BEING DISTRIBUTED IN THE MODERN LAKE. FOUR LAKE MARGIN STUDY LOCALITIES WERE EXAMINED IN DETAIL: (1) AN AREA OF BASALTIC COLLUVIAL HEADLANDS; (2) AN AREA OF SAND, SANDY SILT AND SILTY MUD SUBSTRATES; (3) AN AREA OF HIGHLY VARIABLE SUBSTRATE CONDITIONS; AND (4) AN AREA OF ALTERNATING BASALTIC HEADLANDS AND GRAVEL/SHINGLE TERRACES. BASED UPON QUANTITATIVE OBSERVATIONS IN THESE AREAS AND QUALITATIVE OBSERVATIONS ELSEWHERE IN THE LAKE, WE BELIEVE THAT TWO INTERACTING FACTORS HAVE THE GREATEST INFLUENCE ON THE DISTRIBUTION OF NEARSHORE CLASTICS. THE FIRST IS A SEDIMENT DISTRIBUTION SYSTEM WHICH IS PRIMARILY DEPENDENT ON LOCALIZED SUPPLY, VIA ROCKFALL AND INTERMITTENT STREAMS. THE SECOND IS THE PRESENCE OF PHYSIOGRAPHIC BARRIERS, PRINCIPALLY FAULTED AND ERODED VOLCANIC FLOWS, WHICH BORDER ON LOCAL COARSE SEDIMENT DELIVERY SYSTEMS AND ISOLATE THEM FROM ADJACENT SYSTEMS. VOLCANIC BARRIERS MAY OPERATE AT VARIOUS SCALES IN REGULATING THE DELIVERY SYSTEMS OF CLASTIC SEDIMENTS IN RIFT LAKES, FROM LOCALIZED FACIES DISRUPTION, AS OBSERVED IN LAKE TURKANA, TO THE ISOLATION OF ENTIRE SEDIMENTARY BASINS. AT THE LARGEST LEVELS THE PRESENCE OR ABSENCE OF VOLCANIC ACTIVITY MAY HAVE AN IMPORTANT BEARING ON THE CONTROVERSY OF HYDROCARBON ACCUMULATION IN RIFT LAKES.

From Frostick, L. E. et al. (eds) 1986, Sedimentation in the African Rifts, Geological Society Special Publication No. 25, pp. 127-39.

DISPERSAL AND BROODING BEHAVIOR AS FACTORS IN THE EVOLUTION OF LACUSTRINE SPECIES SWARMS: EVIDENCE FROM LAKE TANGANYIKA

A. S. COHEN AND M. JOHNSTON

EFFECTIVE DISPERSAL MECHANISMS ARE CRITICAL FOR MOST LACUSTRINE ORGANISMS. LACUSTRINE ENVIRONMENTS TEND TO BE GEOLOGICALLY EPHEMERAL AND EFFICIENT DISPERSAL IS IMPORTANT FOR CONTINUAL RECOLONIZATION OF APPROPRIATE HABITATS. HOWEVER, WHEN A LAKE PERSISTS FOR GEOLOGICALLY LONG PERIODS OF TIME, SELECTION PRESSURES FOR EXCELLENT DISPERSAL MECHANISMS ARE RELAXED. UNDER SUCH CIRCUMSTANCES, CLADES OF LACUSTRINE BROODING ORGANISMS, WHICH ARE OFTEN POOR DISPERSERS, HAVE BOTH RADIATED AND SUFFERED EXTINCTIONS AT ACCELERATED RATES.

PATTERNS OF INTER- AND INTRAPOPULATION VARIABILITY FOR TWO ENDEMIC, LITTORAL GASTROPODS FROM LAKE TANGANYIKA, LAVIGERIA NASSA (A BROODER) AND SPEKIA ZONATA (A NONBROODER) PROVIDE EVIDENCE SUPPORTING THIS CONTENTION. GENE FLOW BETWEEN POPULATIONS OF LACUSTRINE BROODERS LIKE L. NASSA MAY BE GREATLY INHIBITED BY EXTREME LOCALIZATION OF GENE POOLS AND A LACK OF VAGILITY AMONG JUVENILES, EVEN IN THE ABSENCE OF ECOLOGICAL BARRIERS TO DISPERSAL. L. NASSA POPULATIONS ARE CHARACTERIZED BY STRONG INTERPOPULATION MORPHOLOGIC VARIABILITY AND INTRAPOPULATION UNIFORMITY (PARTICULARLY WITH REGARDS TO SHAPE CHARACTERISTICS) DESPITE THEIR BROAD SUBSTRATE TOLERANCES. EXTREME GENETIC ISOLATION MAY CAUSE SUCH POPULATIONS TO UNDERGO RAPID SPECIATION AND EXTINCTION, DUE TO THE VAGARIES OF SMALL POPULATION SIZES.

MORPHOLOGICAL VARIATION BETWEEN SPEKIA ZONATA POPULATIONS IS LESS PRONOUNCED AND IS DOMINATED BY SIZE DIFFERENCES WHICH ARE PROBABLY ECOPHENOTYPIC. S. ZONATA MAY BE DISPERSED AT THE JUVENILE STAGE, BUT ADULTS ARE ESSENTIALLY SESSILE AND HAVE STRONG HABITAT SPECIFICITY. LIMITED INTERPOPULATION SHAPE DISTINCTIVENESS IN S. ZONATA SUGGESTS THAT POPULATION INTERACTIONS OCCUR VIA LARVAL RECRUITMENTS FOR THIS SPECIES.

Fourth North American Paleontological Convention, Boulder, Colorado.

OSTRACODES AS INDICATORS OF PALEOHYDROCHEMISTRY IN LAKES: A LATE QUATERNARY EXAMPLE FROM LAKE ELMENTEITA, KENYA

ANDREW S. COHEN AND CHRIS NIELSEN

FOSSIL OSTRACODES PROVIDE A USEFUL WAY OF INTERPRETING THE HYDROCHEMICAL HISTORY OF LAKES. THE TOLERANCES OF MANY OSTRACODE SPECIES TO PARTICULAR HYDROCHEMICAL PARAMETERS ARE KNOWN BASED UPON STUDIES OF LIVING TAXA BY COHEN ET AL. (1983) FROM EASTERN AND SOUTHERN AFRICA RANGE ASSEMBLAGES.

A HYDROCHEMICAL ANALYSIS OF OSTRACODES APPLIED TO FOSSILS FROM A RADIOCARBON-DATED CORE FROM LAKE ELMENTEITA, A SMALL RIFT-VALLEY LAKE OF CENTRAL KENYA, SUGGESTS THAT ABOUT L2,000 YEARS B.P., ELMENTEITA WAS A SMALL, CLOSED LAKE OF RANGE IV SALINITY AND ALKALINITY. IT UNDERWENT A PERIOD OF DECREASING SALINITY AND AKLALINITY, PASSING THROUGH RANGE III TO A RANGE II, HIGH-WATER PHASE, ABOUT 10,000 YEARS B.P. THE LAKE REMAINED IN RANGE II OR FLUCTUATED SLIGHTLY, PRIOR TO ITS RAPID RETURN TO A RANGE IV, HIGHLY ALKALINE AND SALINE, SMALL-LAKE CONDITION ABOUT 8,000 YEARS B.P.

THE RESULTS OF THIS STUDY ARE COMPATIBLE WITH OTHER STUDIES OF LAKE ELMENTEITA'S QUATERNARY HISTORY, AS WELL AS REGIONAL STUDIES DEALING WITH LAKE LEVELS AND PALEOCLIMATE IN EAST AFRICA. MORE BROADLY, THESE RESULTS DEMONSTRATE THE GREAT POTENTIAL FOR RECOGNIZING REGIONAL PALEOHYDROLOGIC AND PALEOCLIMATIC TRENDS FROM TROPICAL LACUSTRINE OSTRACODES DERIVED FROM CORES.

Palaios, 1986, v. 1, p. 601-609