DOE/ER/75673

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Summary and Significance of DOE Trainee Research

Four students received awards and one has completed his doctoral degree (Kevin Henke). Another, Michael Bosela, has completed the requirements and his degree is pending. Michelle Applebee and Charro Gruver are continuing their programs and will complete them over the next two years.

The DOE traineeships resulted in the preparation or submittal of six papers to scholarly journals, three presentations at regional and national meetings and one at an international meeting, and three abstracts and proceedings (Table 1).

Table 1. Summary of Accomplishments.

Student/Mentor	Manuscripts	Presentations	Abstracts/ Proceedings
Applebee/Pierce	1 submitted	1	1
Bosela/Cheng	2 in preparation		2
Gruver/Hammond	1 submitted	3	
	1 in preparation		
Henke/Perkins	1 in press		
Total	6	4	3

We have no objection from a patent standpoint to the publication or dissemination of this material.
Office of Intellectual Property Counsel
DOE Field Office, Chicago
Date August 12 1999

A technical description of the work performed by each trainee, prepared by the mentors, follows.

Environmental Detection of Sulfide by Coulometric Argentometry

David T. Pierce, Ph.D.
Department of Chemistry
University of North Dakota
Grand Forks, North Dakota
(Trainee: Michelle Applebee)

Sulfide (S^{2-}), the most reduced form of sulfur, is formed in water by the action of anaerobic bacteria on organic matter and occurs naturally in crude petroleum products. Numerous problems are associated with its presence. The least damaging but certainly most readily perceived problem is nuisance odor. Because sulfide is readily protonated, wastewaters containing sulfide have a high potential to emit volatile H_2S into the air. Odor of this species can be detected readily at the sulfide concentrations of 0.1 mg L^{-1}. A related problem is toxicity of $_H2S$, which is approximately the same as cyanide gas. Deaths have resulted from levels exceeding only 0.03% in the air and more wide-spread health problems such as reduced lung function have been documented for chronic exposure to low levels. Finally, broad economic problems area associated with the corrosiveness of sulfide and H_2S towards cement-bonded materials. The problem is most severe when solution conditions change from anaerobic to aerobic. Corrosion occurs when H_2S is converted to sulfuric acid by aerobic bacteria that adhere to concrete surfaces. The acid can attack the lime component (CaO) of the cements bonding and converts it to the more soluble and brittle gypsum($CaSO_4$).

The level of sulfide in industrial and municipal wastewaters has a tremendous impact on public acceptance and safety as well as the longevity of concrete infrastructure. Early detection and long term monitoring of sulfide is beneficial in mitigating both monetary and

health-related problems. By locating problem areas, on-site remediation can be implemented to reduce sulfide concentration. These steps can save thousands of dollars to rebuild sewer systems and handling equipment. Also, industries can have better relations with their local community as well as a safer work environment for their employees. by providing accurate measurement of the sulfide concentration at work sites and treatment facilities, employee exposure can be limited or proper safety guidelines an be established, such as the use of respirators.

Unfortunately, the standard methods presently used to analyze for sulfide are difficult to automate and suffer from numerous chemical and solution interferences. More importantly, these methods generally detect sulfide only if it is present in quantities greater than 1 mg L^{-1}. These detection limits are not sufficient to screen for low levels that can lead to nuisance odor, long-term corrosion, and impaired health.

An automatic method to determine ppb sulfide levels in wastewaters was designed using the method of coulometric argentometry. A detection limit of 2.5 g L^{-1} S^{2-} and a linear range of nearly 500 fold was obtained. The method is nearly free of chemical interferences and is not affected by solution turbidity. Analysis is performed with little or no sample pretreatment, allowing for sample throughput of up to 6 samples per hour. Extensive testing on real samples from industrial and municipal wastewater facilities has demonstrated the precision and accuracy of the method. A new field portable design has been built and tested.

List of Publications and Presentations Supported by DOE Traineeship(* denotes trainee)

1. "Determination of Low Level Soluble Sulfide in Wastewater by Coulometric Argentometry" Applebee*, M.S.; Pierce, D.T. EPSCoR Joint North Dakota/South Dakota State Conference; Brookings, SD, September, 1997.

2. "Part-per-billion Determination of Sulfide by Coulometric Argentometry" Pierce, D.T.; Applebee*, M.S.; Lacher, C.; Bessie, J.; submitted to *Environmental Science and Technology*, October, 1997.

3. "Determination of Sulfide by Coulometric Argentometry using the Tekmar DX-25 Volatile Organic Halide Analyzer" Pierce, D.T.; Lacher, C.; Applebee*, M.S.; Bessie, J. 1998 Inorganic Conference Proceeding of the American Water Works Association (AWWA), San Antonio, TX.

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Curriculum Vitae
Michelle S. Applebee

Education: Doctor of Philosophy in Analytical Chemistry
expected December, 2000
University of North Dakota—Grand Forks
David T. Pierce, Advisor

Bachelor of Science in Chemistry ACS, December, 1995
University of Wisconsin—LaCrosse

Graduate School Awards and Honors:

1996 – Summer NASA Research Fellowship
1996/97 – DOE Traineeship

Professional Experience:

University of North Dakota, Grand Forks, ND: 1996, Teaching Assistant for general chemistry.

Davy Laboratories, LaCrosse, WI: 1994-1995, Performed analysis of wastewater samples using EPA and standard methods. Tests included: BOD, NH_2 by Kjeldahl, suspended solids, and color.

Professional Affiliations: American Chemical Society and Iota Sigma Pi

Presentations and Publications:

"Part-per-billion Determination of Sulfide by Coulometric Argentometry" Pierce, D.T.; Applebee, M.S.; Lacher, C.; Bessie, J.; submitted to *Environmental Science and* Technology, October, 1997.

"Determination of Low Level Soluble Sulfide in Wastewater by Coulometric Argentometry" Applebee, M.S.; Pierce, D.T. EPSCoR Joint North Dakota/South Dakota State Conference; Brookings, SD, September, 1997.

"Determination of Sulfide by Coulometric Argentometry using the Tekmar DX-25 Volatile Organic Halide Analyzer" Pierce, D.T.; Lacher, C.; Applebee, M.S.; Bessie, J. 1998 Inorganic conference Proceeding of the American Water Works Association (AWWA), San Antonio, TX.

"Introduction of Inductively Coupled Plasma to Undergraduates", Taylor, P.J.; Greseth, S.L.; Applebee, M.S.; Harmon, M.; Olsen, B. ACS Regional Meeting, LaCrosse, WI, 1995.

"One and Two Dimensional NMR of -iodone", Applebee, M.S.; Greseth, S.L.; McKelvey, R.; ACE Regional Meeting , LaCrosse, WI, 1995.

Curriculum Vitae
David T. Pierce

Educational Background
B.S. 1985 McGill University (Montreal, Canada); Major: Chemistry
Ph.D. 1991 University of Vermont (Burlington); Analytical Chemistry (William E. Geiger)

Professional Experience
1990-92 Postdoctoral Research Fellow, University of Texas at Austin (Allen J. Bard)
April 1992 Research Fellow, Technical University, Budapest, Hungary (Erno Pungor)
1992-present Assistant Professor of Chemistry, University of North Dakota
1993 Research Associate with the North Dakota Mining and Mineral Resources Research Institute, University of North Dakota

Honors and Awards
1992 3M Corporation, Non-Tenured Faculty Award
1994 Nomination for Outstanding Faculty Award
1995 University of North Dakota, Summer Research Professorship
1995 National Honorable Mention, ACS Student Affiliates chapter(advisor)

Selected Publications (16 total)

"Electrochemical Remediation of Metal-Bearing Wastewaters – Part I. Copper Removal from Simulated Mine Drainage Waters." T.L. Hatfield; T.L. Cox, and D.T. Pierce *Journal of Applied Electrochemistry*, **1996**, *26*,567-574.

"Effect of Ligand Structure, Solvent and Temperature on the Electrochemical Behavior of Polyarenc-Iron Complexes", A.S. Abdelaziz, C.R. deDenus, K.M. Epp, S. Smith, R.J. Jaeger, and D.T. Pierce *Canadian Journal of Chemistry*, **1996**, *74*, 650-657.

"Oxidatively Induced Isomerization of Square-Planar[Ni(1,4,8,11-tetraazacyclo-tetradecane)]$(ClO_4)_2$", D.T. Pierce, T.L. Hatfield, E.J. Billo, and Y. Ping *Inorganic* Chemistry, **1997**, *36*, 2950-2955.

"Electrochemical Remediation of Metal-Bearing Wastewaters – Part II. Corrosion-BasedInhibition of Copper Removal by Iron(III)", T.L. Hatfield and D.T. Pierce *Journal of Applied Electrochemistry*, in press.

"Part-per-billion Determination of Sulfide by Coulometric Argentometry", Michelle S. Applebee, Craig Lacher, Jerry Bessie, and David T. Pierce *Environmental Science and* Technology, submitted 10/97.

V. Graduate Students Advised (total 3)
Thomas L. Hatfield, Ph.D. 1997, 3M Corporation
Richard J. Jaeger (Ph.D. expected 8/98)
Michelle S. Applebee (Ph.D. expected 12/2000)

Genetic Transformation of Hybrid Aspens for Mass Propogation

Zong-Ming Cheng, Ph.D.
Department of Plant Sciences
North Dakota State University
Fargo, North Dakota
(Trainee: M. J. Bosela)

The project supported by the DOE traineeship from 1/1996 to 12/1997 involves genetic engineering of aspens with auxin biosynthesis gene under different regulatory promoters. The project has two goals. In the basic science. we are interested in studying the basic mechanism of adventitious rooting hardwood cuttings from trees. Our practical goal is to develop a commercially applicable mass propagation system for aspens and hybrid aspens which can be used for "Biomass-For-Energy" plantations.

Rooting from hardwood cuttings of trees is one of the propagation methods to mass propagate trees for nurseries and commercial forestry and pulp/paper industries. This method is preferred to others because not only can it maintain the genetic make-ups of selected genetically improved trees, but also it is the least costly method due to less energy, water, pesticide and labor consumption. However, rooting from hardwood cuttings for the vegetative propagation of woody plants is only limited to some species. Aspens are among those species which are very difficult to propagate with hardwood cuttings. To solve this problem, the basic mechanism for rooting induction from hardwood cuttings must be better understood. This problem has been studied for many decades, yet much is still unknown why some species are easy and other are difficult to root from hardwood cutting.

The research in my laboratory focuses on utilizing biotechnological approaches, especially genetic engineering technology, to address this very difficult problem facing horticultural and forestry industries. Genetic engineering an aspen (or any other tree species) requires two stages. The first stage involves developing a model transformation system which involves three steps: to develop an in vitro micropropagation system, to develop a reliable regeneration system, to develop a system to introduce a gene into an aspen. The second stage also involves two steps: to introduce genes of interest. in this case "rooting-inducing"' genes into aspens and then to characterize the functions of introduced genes and determine the rooting capability of the genetically engineered aspens.

When Mr. Michael Bosela was arrived in January, 1996, we were in the second step of the stage 1. We had developed a micropropagation system and a regeneration system for one of three aspen hybrids. Primarily with Mr. Bosela's effort, we have progressed to the second step of the second stage. Major progress accomplished by Mr. Bosela is briefly described below.

1). **Modification of the regeneration system**. In the earlier regeneration system, we used leaf tissues and regenerated plants directly. This system was later found not working in regenerating plants from transformed tissues. Michael developed a regeneration system with a callus induction phase. This new regeneration system allowed us to move forward to genetically engineering aspens. Michael also extended the regeneration system to other two aspen hybrids.

2). **Development of a model transformation system.** Mostly with Michael's work, a model transformation system now is developed in my laboratory to introduce genes into aspens, the most limiting step in this research area. The system is quite efficient,

requiring only 6-8 weeks to obtain genetically engineered plants. This system has also been extended to another two aspen hybrids, although efficiency is lower.

3). **Introduction** of genes of **interest into aspens.** Michael has finished introduce the auxin biosynthesis gene, iaaM into aspens. This gene is under control of four different promoters, with
equal numbers of controls. This is very time-consuming, very laborious work. With Michael's diligence and hardworking, now we have many transformed aspen plants further characterization, which will be the final step in this research. Although the work will be challenging, I am confident that Michael will continue the excellent work. In the third year. Michael will involve many molecular biology techniques, such as Southern blot, Northern blot, polemerase chain reaction, gene expression and auxin quantitation with HPLC. Finally Michael will conduct some greenhouse testing in rooting with hardwood cuttings.

By the time Michael completes his research and training, he will become a well-rounded scientist with competent skills in the biology, horticulture/forestry and biotechnology and molecular biology. I am confident his skills and training at multi-levels will make him very marketable in the very competitive biotechnological job market.

We have given two presentations in the professional meetings and are currently preparing at least two refereed publication. Potentially 2-3 more refereed publications are possible.

Relations to the Department of Energy's Mission

The Department of Energy has actively involved in research to develop alternative fuel sources, so the Nation become less dependent on petroleum-based energy. One of the program the DOE has been Energy from Biomass and Electricity from Biomass. With over two decades of research effort, it appears that the chemical process to convert biomass to liquid fuel or electricity is feasible. However, the too high cost of the raw materials for biomass-based energy production has not become commercially feasible. Therefore, any measure which can substantially reduce the cost for producing the raw materials without causing a environmental burden will significantly increase the chance of commercialization of biomass-based, clean and renewable energy, as a result, making U.S. economy more competitive and self-sustainable.

This project with which the DOE traineeship was associated was previously funded by the Department of Energy's "Energy from Biomass" Program through the Consortium for Plant Biotechnology Research (CPBR). Support has also been received from a Minnesota-based paper company (Blandin Paper) and from NDSU Research Foundation. The preproposal based on this research has also been selected by the DOE-CPBR for full proposal in the 1998 competition, with potential funding of $50,000-100,000 per year funding for two years.

In summary, this DOE traineeship has allowed Mr. M. Bosela to receive quality training and has also allowed me to advance my project for more funding possibility in the future.

List of Publications and Presentations Supported by DOE Traineeship

Abstracts/Proceedings:

Z.-M. Cheng, Bosela, M. J., W. A. Sargent, and J. P. Schnurr. 1997. Transformation of hybrid. Aspens with iaaM and rolB for rooting enhancement. TAPPI Proceedings. p.505-506

Bosela, M. J., J. P. Schnurr, Z.-M. Cheng, and W. A. Sargent. 199_. Agrobacterium-mediated transformation of three elite hybrid. Aspens. HortScience 32:535

Manuscripts in preparation:

Bosela, M. J., J. P. Schnurr, Z.-M. Cheng. 199_. Optimized plant regeneration from aspen hybrids. To be submitted to Plant Cell Reports.

Bosela, M. J., Z.-M. Cheng, W. A. Sargent, and J. P. Schnurr. 199_. Agrobacterium-mediated transformation of aspen hybrid. To be submitted to Plant Science.

Curriculum Vitae
Michael Bosela

OBJECTIVE

To obtain a faculty position at a larger research university. To develop a well-funded research program and establish collaborations with other researchers both on and off site. To teach courses relating to my research interests.

RESEARCH INTERESTS

I am interested in the study of plant morphology and organogenesis (both *in vitro* and *in vivo). I* am particularly interested in working with woody plants and have extensive background in this area. I have worked in a molecular biology lab for several years and anticipate that most of my future research projects will have a molecular biology component, but since I have an training in plant histology and plant tissue culture, I am not dependent upon doing molecular work during times of scarce funding.

EDUCATION

Ph.D. of Science, Plant Science Department
North Dakota State University (pending)

Masters of Science, Botany and Plant Pathology Michigan State University (1995)

Bachelor of Arts, Biology
Oberlin College (1991)

RESEARCH EXPERIENCE

Ph.D. Research
Dr. Zong-Ming Cheng (advisor)
Department of Plant Sciences
North Dakota State University
1996- Present

Employed a genetic engineering strategy to determine 1) whether the rooting ability of aspen hardwood stem cuttings is limited by a lack of endogenous auxins and 2) whether chimeric genes consisting of auxin biosynthesis genes and inducible promoters could be used to create easy-to- root aspen lines.

Masters Research
Dr. Frank W. Ewers (advisor)
Department of Botany and Plant Pathology
Michigan State University
1992-1995
Determined the mode of origin of root sprouts in the clonal tree, *Sassafras albidum.* Also investigated the structure and hydraulic architecture of Sassafras root systems.
Work/Learn Intern
Dr. Hanne Rasmussen (supervisor)
Smithsonian Environmental Research Center
1/1992- 5/1992

Studied the root systems of a native orchid, *Tipularia discolor.* Tested for differences in mycorrhizal colonization as a function of root orientation (vertical, horizontal, etc.) and soil type.

Other research experience

At Michigan State University I participated in two lab rotations. In one case, I compared the time course of stem embolism (air blockage) and leaf fall in tree with contrasting phenologies and in the other I collected fungal isolates from virulent and avirulent cankers of recovering chestnut populations for vegetative compatibility testing and virus screening (the chestnut blight pathogen is susceptible to infection by a dsRNA virus that causes reduced virulence).

TEACHING EXPERIENCE

During my tenure at Michigan State I taught as a laboratory instructor for both introductory and upper level (Plant Anatomy, Plant Morphology and Evolution, and Aquatic Plant Biology) courses. I received both departmental and college-level teaching awards (see below). At North Dakota State University I have taught as a laboratory instructor for Plant Tissue Culture and I am currently teaching a Plant Propagation Lab.

LEADERSHIP AND ORGANIZATIONAL EXPERIENCE

President, Plant Science Graduate Student Organization North Dakota State University 1/1997 - 1/1998

Vice-President, Plant Science Graduate Student Organization North Dakota State University 1/1996 - 1/1997

President, Horticulture and Forestry Graduate Student Organization North Dakota State University 8/1996 - 8/1997

AWARDS AND HONORS

1993-1994 Fields Teaching Award Department of Botany and Plant Pathology, Michigan State University

1994-1995 Teaching Excellence Award College of Natural Sciences, Michigan State University

SELECTED SKILLS

Laboratory: Agrobacterium-mediated plant transformation, PCR, Southern and Northern Blotting, plant tissue culture (shoot and callus culture, organogenesis), plant histology (paraffin embedding and general staining), laser scanning confocal microscopy

Computer: Familiar with SPSS, Axum, CorelDraw, Adobe Photoshop, Microsoft Word, WordPerfect, Microsoft Excel, Microsoft Powerpoint.

Photography: Over 7 years of B&W darkroom experience. Worked as a yearbook photographer in both college and high school.

MEMBERSHIP IN PROFESSIONAL ORGANIZATIONS

Botanical Society of America Association for the Advancement of Science Sigma Xi Scientific Research Society

PUBLICATIONS

M.S. Thesis:

Bosela, M.J. 1995. The Mode of Origin of Root Buds and Root Sprouts in the Clonal Tree, *Sassafras albidum.* M.S. Thesis, Michigan State University, East Lansing, Mi.

Abstracts:

Bosela, M.J., J.P. Schnurr, Z. M. Cheng, and W.A. Sargent. 1997. Agrobacterium-mediated transformation of three elite hybrid aspens. HortScience 32:535.

Cheng, Z.M. M.J. Bosela, W. A. Sargent, and J.P. Schnurr. 1997. Transformation of hybrid aspen with iaaM and rolB for rooting enhancement. TAPPI Proceedings, 1997; Oct 19-23, San Francisco, CA. TAPPI Press, Atlanta, GA.

Referred Publications:

Bosela, M.J., and F. W. Ewers. 1997. The mode of origin of root buds and root sprouts in the clonal tree, *Sassafras albidum* (Lauraceae). American Journal of Botany 84:1466-1481.

Bosela, M.J., J. P. Schnurr, Z. M. Cheng, and W.A. Sargent. 1998. Variable affecting the Agrobacterium-mediated transformation of hybrid aspens. (in preparation).

REFERENCES AVAILABLE UPON REQUEST

CURRICULUM VITA
ZONG-MING CHENG

Education:

Ph.D., Horticulture/Plant Molecular Biology, 1991, Cornell University, Ithaca, NY
M.S., Pomology/Plant Genetics, 1988, Cornell University, Ithaca, NY
B.S., Pomology, 1982, Nanjing Agricultural University, P.R. China

3. Research Interests:

Woody plant biotechnology/genetics/breeding for disease, insect and herbicide resistance; Phytoplasma genome study and woody hosts/phytoplasma interactions; Adventitious rooting mechanisms in woody plants and micropropagation.

Professional Experience:

Associate Professor, 7/1997-present
Department of Plant Sciences, North Dakota State University, Fargo, ND
Assistant Professor, 11/1990-6/1997.
Department of Plant Sciences, North Dakota State University. Fargo. ND
Graduate Research Assistant, 9/1985--l 1/1990
Department of Horticultural Sciences, Cornell University, Geneva, New York

Refereed Publications (published and accepted in the last five years):

1) Guo, Y. H., J. A. Walla, Z.-M. Cheng and L-M. Lee. 1996. X-disease confirmation and distribution in chokecherry in North Dakota. Plant Disease 80:95-102.

2) Guo. Y. H., Z.-M. Cheng, J. A. Walla. Z. -Zhang 1998. Diagnosis of X-disease phytoplasma in stone fruits by a monoclonal antibody developed directly from a woody plant. Accepted to Journal Environ. Hort.

3) Guo, Y. H.. /.-M. Cheng.J. A. Walla and Z. Zhang. 1998. large-scale screening for X-disease phytoplasma infection in chokecherry. Accepted to HortScience

4) Cheng, Z.-M. and N.-Q. Shi. 1995. Micropropagation of mature Siberian elm in two steps. Plant Cell Tissue Organ Culture 41:197-199.

5) Park, Y. D., D. H. Ronis, A. A. Boe, and Z.-M. Cheng. 1995. Plant regeneration from leaf tissues of four North Dakota genotypes of potato *(Solanum tuberosum* L.). American Potato Journal 72:329-338.

6) Schnurr, J. P., Z.-M. Cheng and A. A. Boe. 1996. Effect of plant growth regulators on sturdiness of Jack pine seedlings. J. of Environ. Hort.. 14:228-23) 0

7) Kapaun, J.A. and Z.-M. Cheng. 1997. Plant regeneration from leaf tissues of Siberian elm. HortScience 32:301-303.

8)Cheng, Z.-M N.-Q. Shi. D. E. Herman, and T. Capps. 1997. Genetic Improvementof American elm through genetic engineering. J. of Forestry 95:24-27

9) Cheng, Z.-M., A. A. Boe, J. P. Schnurr and D. E. Herman. 1997. 'Fargo': An Asian White Birch for the Northern Plains. HortScience 32:1304-1305.

10) Cheng, Z.-M., J. A. Schnurr, and J. A. Kapaun. 1998. Timentin as an effective antibiotic for suppression of *Agrobacterium tumefaciens* in genetic transformation. Plant Cell Reports. In press.
11) Park, Y.-D, D. H. Ronis, M. E. Duysen, Z.-M. Cheng and J. H. Lorenzen. 1996. Transformation of five different potato genotypes for resistance to potato virus Y. Asian Potato Journal. In press.

Book Chapters:

1 . Cheng, Z.-M. 1994. Genetic Engineering. In: R. M. Fu (ed.) Fruit and Melon Biotechnology pp. 331-389 Agriculture Press. Beijing. China (in Chinese)

2. Shi N.-Q. and Z.-M. Cheng. 1994. PCR technology and application. In: R. M. Fu (ed.) Fruit and Melon Biotechnology. pp. 390-402 Agriculture Press. Beijing. China (in Chinese)

Other Published Abstracts and Manuscripts in Preparation Related to This Traineeship:

Abstracts/Proceedings:

1. Z.-M. Cheng, Bosela, M. J., W. A. Sargent, and J. P. Schnurr. 1997. Transformation of hybrid. Aspens with iaaM and rolB for rooting enhancement. TAPPI Proceedings. p.505-506

2. Bosela, M. J., J. P. Schnurr, Z.-M. Cheng, and W. A. Sargent. 199. Agrobacterium-mediated transformation of three elite hybrid. Aspens. HortScience 32:535

Manuscripts in preparation:

1. Bosela, M. J., J. P. Schnurr, Z.-M. Cheng. 199. Optimized plant regeneration from aspen hybrids, To be submitted to Plant Cell Reports.

2. Bosela, M. J., Z.-M. Cheng, W. A. Sargent, and J. P. Schnurr. 199 Agrobacterium-mediated transformation of aspen hybrid. To be submitted to Plant Science.

Theory of Gravitation with Torsion

Richard T. Hammond, Ph.D.
Department of Physics
North Dakota State University
Fargo, North Dakota
(Trainee: Charro Gruver)

During the one and-a-half year period from September 1996 through December 1997, Charro Gruver conducted research under the mentorship of Professor Richard Hammond. This research was funded by a DOE Traineeship Grant. What follows is a summary of that research.

Hammond and Gruver are developing and expanding a theory of gravitation with torsion. This theory, as originally derived by Hammond, seeks to explain the intrinsic spin of fundamental particles as the source for a spin field, and the forces to which this field gives rise. Charged particles produce and interact with the electro-magnetic field, and all matter and energy produce and interact with the gravitational field. In the same way, particles with intrinsic spin should produce and interact with a ``spin" field. This field is torsion.

In Hammond's original formulation the ``spin" of fundamental particles is not a physical rotation, but is instead an intrinsic property like charge or mass. This intrinsic property gives rise to the spin angular momentum of theparticle and produces its magnetic moment, as in the case of the electron. This spin also gives rise to a propagating field, called torsion. This field allows for the transfer of energy from one particle to another, resulting in a spin-spin interaction. Independent experimentation by other groups is under way to attempt to measure this sort of interaction. If the existance of this force can be verified the implications could be astounding. A non-electromagnetic, propagating wave will have been discovered, opening up completely new avenues for exploration and communication.

In the Dirac formulation of the theory, which puts it into the language of quantum mechanics, Hammond discovered that the theory required the presence of a scalar field. The result of this is that the torsion is produced not only by spin, but by the scalar field as well. Gruver's major contribution to this work was to develop the torsion theory to include the scalar field, and to ensure that the physics of the previously established theory remained sound.

The generalization of the original theory was developed in such a way that the torsion field is made up of contributions from the spin field and a spin-independent scalar field. The field equations and equations of motion were derived and examined to see if they were physically sound. The equations for angular motion were developed, and scrutinized to see if the conservation of angular momentum plus spin was achieved. The results of this research reveal that angular momentum and spin are indeed conserved. The equations of motion yield the correct forces for gravitation in the absence of torsion, and they yield the previous results for gravitation and spin when the scalar field is zero. These results show that this is a very strong theory which lends itself well to generalization, has predictive power, and yields physically meaningful results which should be eventually testable, as technology allows.

The following is a list highlighting some of the presentations resulting from this work.

"Scalar Field from Dirac Coupled Torsion" presented by R. Hammond at the Eighth Marcel Grossmann Meeting, held in Jerusalem, summer 1997.

"Astrophysical Consequences of Gravitation with Torsion" presented by Charro Gruver at the 89th Annual Meeting of the North Dakota Acadamy of Science, held in Grand Forks, ND, Sept. 15-16, 1997.

"A Theory of Gravitation with Torsion and a Scalar Field"presented by Charro Gruver at the Seventh Midwest Relativity at Meeting, held Washington University in St. Louis, MO, Nov. 15-16, 1997.

"Tensor-Scalar Torsion", by Charro Gruver, R. Hammond, and P. Kelly, being submitted to General Relativity and Gravitation for publication.

"Detailed Analysis of a Structured Source for Gravitation with Torsion of the type $H\mu\nu\sigma=\Psi[\mu\nu,\sigma]$" by Charro Gruver and R. Hammond, currently in preparation for publication.

Curriculum Vitae
Charro L. Gruver

Positions Held

Graduate Student: North Dakota State University Department of physics,(1995-1998).

Graduate Research Assistant, funded by NSF EPSCoR: North Dakota State University, (1998-current).

Graduate Research Assistant, funded by DOE Traineeship: North Dakota State University, (1996-1997).

Graduate Teaching Assistant: North Dakota State University, (1996).

Graduate Research Assistant, funded by NASA JOVE: North Dakota State University, (1995).

Education

B.S. double major in Physics and Mathematics, Northeastern State University, Talequah, Oklahoma, 1995.

Research Interests

Generalized theories of gravitation with torsion.
Experimental tests of general relativity.
Magnetohydrodynamic wave processes in earth's ionosphere.\

Honors

DOE Traineeship, $22,000, 1996-1997.

Funding}

NASA, North Dakota Space Grant Program, $1600, 1996.

Presentations

"A Theory of Gravity with Torsion and a Scalar Field," C. Gruver, R. T. Hammond, and P. F. Kelly, presented at the Seventh Midwest Relativity Meeting, Washington University, St. Louis, MO. 1997.

"Astrophysical Consequences of Gravitation with Torsion," C. Gruver, presented at the 89th Annual Meeting of the North Dakota Academy of Science, University of North Dakota, Grand Forks, ND, 1997.

"Scalar Field from Dirac Coupled Torsion," R. T. Hammond, P. F. Kelly, and C. Gruver, presented at the international meeting, Marcel Grossmann Eight, Jerusalem, 1997.

Publications

"Tensor-Scalar Torsion," C. Gruver, R. T. Hammond, and P. F. Kelly, being submitted to General Relativity and Gravitation, Jan, 1998.

Chemistry and Environmental Implications of Thio-Red® and 2,4,6-Trimercaptotriazine Compounds

Dexter Perkins, Ph.D.
Department of Geology and Geological Engineering
University of North Dakota
Grand Forks, North Dakota
(Trainee: Kevin Henke)

During his EPSCoR appointment in 1997, Kevin R. Henke completed his dissertation and graduated in December with a Ph.D. in geology from the University of North Dakota (Henke, 1997). With EPSCoR funding, Kevin synthesized and identified the crystalline structures of calcium, strontium, and barium trimercaptotriazine (TMT) compounds. In particular, his efforts concentrated on $Ba_3(C_3N_3S_3)_2 \bullet 8H_2O$, $BaH_4(C_3N_3S_3)_2 \bullet 4.5H_2O$, $CaH_4(C_3N_3S_3)_2 \bullet 11H_2O$, and $SrH_4(C_3N_3S_3)_2 \bullet 11H_2O$.

Degussa Corporation USA of Allendale, New Jersey, markets sodium 2,4,6-trimercaptotriazine ($Na_3C_3N_3S_3 \bullet 9H_2O$, also called TMT-55) to precipitate mercury and other heavy metals from waste waters and contaminated ground waters. Although TMT-55 is a widely used commercial product, before Kevin's studies, virtually no information was available on the chemistry and crystalline structure of TMT-55, how the product precipitates metals from aqueous solutions, and the chemistries and stabilities of the heavy metal precipitates. Before 1997, Kevin determined the chemistry and crystalline structure of TMT-55 and performed laboratory batch leaching studies to evaluate the stabilities of three varieties of mercury TMT compounds in water. The U.S. DOE Y-12 Nuclear Weapons Plant in Oak Ridge, Tennessee, used this information when considering TMT-55 as a possible treatment product for mercury contaminated soils at the facility.

The U.S. EPA classifies barium as a toxic hazard. Literature from Degussa Corporation does not contain any information on precipitating dissolved barium from water with TMT-55 or the properties of any barium 2,4,6-trimercaptotriazine (BaTMT) compounds. In 1997, under EPSCoR funding, Kevin evaluated TMT-55 as a chemical treatment product for removing barium from contaminated water. Additionally, information on barium, strontium, and calcium TMT compounds could be used to predict the chemistry of radium TMT. Radium is a potential radiation hazard in some ground waters associated with natural uranium deposits and could also be present in water at some U.S. DOE nuclear weapons facilities. Because radium is radioactive and research with the element requires extensive training, regulatory permits and safety procedures, studies of BaTMT and other alkaline earth TMT compounds may cheaply and safely provide some preliminary information on whether TMT-55 might precipitate radium and whether research with radium and TMT-55 is warranted.

The solubilities of the alkaline earth TMT compounds are quite high, but decrease from $CaH_4(C_3N_3S_3)_2 \bullet 11H_2O$ (187 grams/liter) to $SrH_4(C_3N_3S_3)_2 \bullet 11H_2O$ (10.4 grams/liter) to $BaH_4(C_3N_3S_3)_2 \bullet 4.5H_2O$ (4.56 grams/liter). Kevin's studies show that the aqueous solubilities of $Ba_3(C_3N_3S_3)_2 \bullet 8H_2O$ and $BaH_4(C_3N_3S_3)_2 \bullet 4.5H_2O$ are probably too high (both are around five grams/liter) for effective barium removal (for details, see chapter 7 in Henke, 1997). *Inorganic Chemistry* will soon publish a summary of the research results on $BaH_4(C_3N_3S_3)_2 \bullet 4.5H_2O$, $CaH_4(C_3N_3S_3)_2 \bullet 11H_2O$, and $SrH_4(C_3N_3S_3)_2 \bullet 11H_2O$ (Henke and Atwood, in press).

Publications under EPSCoR Funding:

Henke, Kevin R. and Atwood, David A., in press, Group 2 complexes of 2,4,6-trimercaptotriazine (TMT): *Inorganic Chemistry*.

Henke, Kevin R., 1997, *Chemistry and Environmental Implications of Thio-Red® and 2,4,6- Trimercaptotriazine Compounds:* Ph.D. dissertation, Department of Geology and Geological Engineering, University of North Dakota, December, 1997, 172p.

Curriculum Vitae
Kevin R. Henke

EDUCATION

Ph.D. Geology, University of North Dakota, Grand Forks, ND, 1997.
Dissertation: *Chemistry and Environmental Implications of Thio-Red® and 2,4,6-Trimercaptotriazine Compounds.*

M.S. Geology, University of North Dakota, Grand Forks, ND, 1984. Thesis: *Archean Metamorphism in Northwestern Ontario and Southeastern Manitoba.*

B.A. Physical Science with minors in physics and geology, Doane College, Crete, NE, 1979.

EXPERTISE

Geochemistry
Environmental chemistry of mercury and other heavy metals
Mineralogy and crystallography
Metamorphic and igneous petrology
Evaluation of commercial wastewater treatment products for removal of heavy metals
Chemistry and aqueous leachability of combustion wastes
Hydrogeology and groundwater contamination
Subsurface waste disposal issues

EMPLOYMENT

Graduate Research and Teaching Assistant in the Geology Department, University of North Dakota, Grand Forks, ND, 1979-1983, 1996-1997 (typical salary $6/hour).

Operated a scanning electron microscope (SEM) and investigated the chemistry of sodium slags in coal ashes and chemistry of minerals in metamorphic rocks for geothermobarometry studies as part of my Master's thesis.

Taught labs in physical geology, historical geology (introduction to paleontology), mineralogy, petrology, and optical mineralogy.

Occasional substitute teacher for mineralogy and environmental geology lectures.

Assisted major professor (Dr. Dexter Perkins III) in writing, editing, and taking photographs for his mineralogy textbook (published in January, 1998).

Awarded EPSCor (U.S. Department of Energy) Fellowship ($18,000/year), 1997.

Chemist and geochemist at University of North Dakota Energy & Environmental Research Center, 1983- 1996 (part time, 1994-1996) ($10 - 17/hour).

Studied chemistries and leaching properties of coal ashes and other wastes with emphasis on selenium, arsenic, barium, boron, and chromium.

Investigated the removal of "heavy metals" from water with sorption and chemical precipitation methods, especially the removal of boron through the precipitation of ettringite-like compounds and sorption of chromium on peat.

Developed computer databases and wrote detailed reports on issues that are important to the natural gas industry.

Postgraduate research position on mercury contamination issues at Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, 1994-1996 ($26,000/year).

Performed subsurface hydrology studies on mercury contaminated site at Y-12 Nuclear Weapons Plant.

Instigated my own Ph.D. dissertation topic and worked alone to find initial technical support.

Investigated the chemistry and properties of Thio-Red®, "wettable" sulfur, TMT-55, pyrite, sphalerite, and other sulfur compounds as they relate to the precipitation of mercury, copper, lead and/or zinc from water.

Investigated the crystalline structure of TMT-55 (2,4,6-Trimercaptotriazine trisodium salt), which is used to remove mercury and other divalent heavy metals from wastewaters.

Investigated the formation and chemistry of polymers (polythiocarbonates?) from reactions between metallic copper or lead and Thio-Red®.

Discovered previously unknown heavy metal trimercaptotriazine compounds, including mercury and manganese varieties.

Investigated the leachability and stability of mercury trimercaptotriazine compounds and possible environmental implications.

Discovered that TMT-55 and Thio-Red® do not precipitate heavy metals as manufacturers claim.

Research support in the organometallic section of the Chemistry Department, North Dakota State University, Fargo, North Dakota, Summer, 1996 ($3000/summer), Jan. 1998 to present ($2000/month).

Synthesized new or rarely studied heavy metal trimercaptotriazine compounds (including varieties with calcium, strontium, barium, manganese, silver, potassium, rubidium, and cesium) and investigated their crystalline properties.

OTHER SKILLS

Statistics

With dictionaries, I can translate articles from German and Spanish. I also have limited experience with other languages.

Photography of thin sections.

Computer languages: Basic, Fortran, and Pascal.

Computer software: Wordperfect, Lotus 1-2-3, Quattro pro, Excel, Q&A, various powder XRD software (such as TREOR90 and GSAS) and others

Experience operating the following analytical equipment: furnace and flame AA, cold vapor AA (mercury, selenium, and arsenic), atomic fluorescence (mercury), powder XRD, ICP, SEM, sulfide electrodes, and CHNS.

SELECTED REFERENCES

Henke, K.R., "Chemistry of Heavy Metal Precipitates Resulting from Reactions with Thio-Red®": *Water Environment Research*, accepted for publication.

Henke, K.R. and Atwood, D.A., "Group 2 complexes of 2,4,6-trimercaptotriazine (TMT)": *Inorganic Chemistry*, v. 37, n. 2, January, 1998, pp. 224-227.

Henke, K.R.; Bryan, J.C. and Elless, M.P., "Structure and Powder Diffraction Pattern of 2,4,6-Trimercapto-s-triazine, Trisodium Salt ($Na_3S_3C_3N_3 \bullet 9H_2O$)": *Powder Diffraction*, v. 12, n. 1, March, 1997, pp. 7-12.

Henke, K.R.; Bogle, M.A. and Turner, R.R., 1996, *The Subsurface Hydrology around Building 9201-2: Results of the July 1994 Water Level Recovery Test, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee:* Environmental Sciences Division, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN, 37831-6036, Y/ER-263, 42p.

Henke, K.R., "Immobilization of Mercury in Soil at a Contaminated Site," *Proceedings of Geological Society of America, 44th Annual Southeastern Section Meeting, April 6-7, 1995*, v. 27, n. 2, March 1995, ISSN 0016-7592, No. 38052, p. 61-62.

Henke, K. R.; Kühnel, V.; Stepan, D. J; Fraley, R. H.; Robinson, C. M.; Charlton, D. S.; Gust, H. M.; and Bloom, N. S., 1993, *Critical review of mercury contamination issues relevant to manometers at natural gas industry sites*: GRI-93/0117, Gas Research Institute, Chicago, 110 pp.

Henke, K.R.; Malterer, T.J.; Moretti, C.J. and Grohs, J.F., "Removal of Trace Elements from Western Fly Ash Leachates Using Minnesota Peats," *Proceedings of the 15th Biennial Low-Rank Fuels Symposium*, 1989, DOE/METC-90/6109, p. 592-613.

Katrinak, K.A.; Benson, S.A.; Henke, K.R. and Hassett, D.J., 1994, "Mercury in North Dakota Lignite," *Fuel Processing Technology*, v. 39, 1994, p. 35-45.

Wentz, C.A.; Moretti, C.J.; Henke, K.R.; Manz, O.E.; and Wiken, K.U., "Use of Fly Ash as a Waste Minimization Strategy," *Environmental Progress*, v. 7, n. 3, 1988, p. 198-206.

Curriculum Vitae
Dexter Perkins

Title: Professor of Geology
Department of Geology and Geological Engineering
University of North Dakota
Grand Forks, North Dakota 58202

Education: Ph.D., Geology, University of Michigan, 1979
M.S., Geology, University of Michigan, 1977
B.S., Geology, University of Rochester, 1973

Academic Positions:

Professor of Geology, University of North Dakota, 1993 - present

Research Associate, Energy and Environmental Research Center, University of North Dakota, 1991 - present

Associate Editor, The American Mineralogist, 1991 - present

Professeur Associée at Université Blaise Pascal, Clermont-Ferrand, France, 1990 (Sabbatical from UND)

Associate Professor of Geology, University of North Dakota, 1986 - 1993

Assistant Professor of Geology, University of North Dakota, 1981 - 1986

Post-Doctoral Research Fellow (with R.C. Newton), University of Chicago, 1979 - 1981

Shell Fellow, University of Michigan, 1979

Pre-Doctoral Research Fellow at the Institute für Kristallagraphie und Petrographie, ETH (with A.B. Thompson), Zurich, Switzerland, 1977

Research Interests:

Dissertation and Post-Doctoral Research - Included field studies, high pressure (piston cylinder) experiments, theoretical calculations and geothermobarometry. Also consulted on radioactive waste disposal.

Current Research - Present projects fall into three main areas: formulation of geobarometers for garnet-granulites; field/ petrologic studies of granulites and migmatites from the Superior Province of Western Ontario, the Minnesota River Valley and parts of the Churchill Province; investigation of mercury contaminations at DOE sites.

Future Research - Major interests are to (1) continue working on environmental problems such as mercury contamination, and (2) to continue investigations of metamorphic rocks from experimental, thermochemical, and petrological points of view.

Publications - Articles and Technical Reports (since 1990)

(All are international refereed journals except for those marked with *)

Perkins, D. (1990) Thermometry and barometry of mafic granulites based on garnet-clinopyroxene-plagioclase-quartz assemblages. NATO Adv. Stud. Pub. Series, 311, 435-450.

Anovitz, L.M., Perkins, D., and Essene, E.J. (1991) On the common metastability of minerals in the system Al_2O_3-SiO_2-H_2O in near-surface rocks. Clays Clay Min., 39, 225-233.

Perkins, D. (1991) Metamorphism of the Kisseynew Gneisses, Trans-Hudson Orogen, northern Saskatchewan. Can. J. Earth Sci., 28, 1664-1676.

Perkins, D. and Vielzeuf, D. (1992) Reinvestigation of fayalite+anorthite=garnet. Contrib. Mineralogist Petrol. 111, 260-263.

Perkins, D., and Vielzeuf, D. (1992) Experimental investigation of Fe-Mg exchange between olivine and clinopyroxene. American Mineralogist 77, 774-783.

Abbas-Hasanie, S.A.F., Lewry, J.F., and Perkins, D. (1992) Geothermometry and geobarometry of high-grade pelites in the Brabant Lake area, eastern La Ronge Domain, northern Saskatchewan. Can. J. Earth Sci. 29, 1686-1700.

Essene, E.J., Anovitz, L.M., and Perkins, D. (1994) Mineral metastability in the system Al_2O_3-SiO_2-H_2O. Clays Clay Min. 42:102-106.

Brady, J.B., Mogk, D.W., and Perkins, D., eds. (1997) Teaching Mineralogy. The Mineralogical Society of America. 406 p.

Perkins, D. (1998) Mineralogy. Prentice Hall. 485p.

Perkins, D. (1998) Instructor's Notes to accompany Mineralogy. Prentice Hall. 60p.

Publications - Abstracts and Short Notes

Perkins, D. (1990) Metamorphism of the Kisseynew Gneisses, Saskatchewan: problems calculating retrograde P-T paths. Geological Society America Abstracts 22, A30.

Perkins, D. (1991) Experimental investigation of Fe-Mg exchange between olivine and clinopyroxene. Transactions of the American Geophysical Union, 72, 513.

Perkins, D. (1991) Garnet-clinopyroxene thermometry revisited. Geological Society America Abstracts 23, A392.
Perkins, D. (1991) Glennie-Kisseynew P-T study 1991: fieldwork and preliminary report. Summary of Investigations 1991, Saskatchewan Geological Survey, Miscellaneous Report 91-4, 66-68.

Abbas-Hasanie, S., Lewry, J.F., and Perkins, D. (1991) Metamorphic P-T Studies in the Jan Lake Area, Hanson Lake Block. Summary of Investigations 1991, Saskatchewan Geological Survey, Miscellaneous Rep, 91-4, 69-71.

Perkins, D. (1992) Future energy needs. Comment in Geological Society America Forum Feedback. GSA Today 2, 3.

Perkins, D. (1992) Blob geology and exotic terranes: a counter-example from the Saskatchewan Canadian Shield. Proc. N. Dakota Acad. Sci. 46, 85.

Abbas-Hasanie, S., and Perkins, D. (1992) Garnet-biotite geothermometry in high-grade gneisses of the Jan Lake area. Summary of Investigations 1992, Saskatchewan Geological Survey Miscellaneous Report 92-4, 117-119.

Perkins, D. (1993) Metamorphism in the southern Kisseynew Domain, Saskatchewan: do pelites tell the truth? Geological Society America Abstracts 25, A102.

Perkins, D. (1994) Turning undergraduate education on its ear. Transactions of the Chapman Conf. on the Scrutiny of Undergraduate Geoscience Education, A27. American Geophysical Union.

Perkins, D. (1994) High T Experiments in Undergraduate Mineralogy Courses: A Fun and Effective Road to Learning. Geological Society America Annual Meeting Abstracts with Program, 26, p A-4-9, 1994.

Perkins, D. (1994) Making Mineralogy Fun and Interesting. Proceedings of Scrutiny of Undergraduate Geoscience Education. American Geophysical Union/American Geological Institute, p 26.

Perkins, D. (1995) Innovations in Classroom Examination Techniques. Contribution summarized in Tobias and Raphael, In-Class Examinations in College Science: New Theory, New Practice. California State University Press.

Brady, J.B., Cheney, J.T., Perkins D., Whelan, P.M., Puffal, A. (1996) Proceedings of Teaching Mineralogy Workshop, July 1996, Northampton, MA, 231pp.

Perkins, D. and Sorensen, P. (1996) Making synthetic minerals in mineralogy lab: teaching students to do science. In, Brady et al., editors, Proceedings of the Teaching Mineralogy Workshop, July 1996, Northampton MA, 189-193.

Perkins, D. (1996) Take home, open book, group exams to promote learning in science: an example from introductory mineralogy. Geological Society America Annual Meeting Abstracts with Program, 28, p A165, 1996.

Perkins, D. and Sorensen, P. (1997) Mineral synthesis and X-ray diffraction experiments. In, Brady et al., editors, Teaching Mineralogy, Mineralogical Society of America, p 81-90.

Sorensen, P. and Perkins, D. (1997) Growing crystals on a microscope stage. In, Brady et al., editors, Teaching Mineralogy, Mineralogical Society of America, p 79-80.

Perkins, D. (1997) A fun an effective exercise for understanding lattices and space groups. In, Brady et al., editors, Teaching Mineralogy, Mineralogical Society of America, p 245-250.

Grants Received (since 1990):

1997: Promoting Student Learning Through Experimental Studies in Geoscience Courses. NSF-ILI ($33,302)

1996: Compositon and Structure of organo-metallic mercury compounds. DOE-EPSCoR Traineeship. ($19,200)

1996: Travel grant to Geological Society of America Meeting UND Faculty Research Committee

1994: "Religion and Energy Use." UND Energy and Environmental Research Center (with D. Scott Lowe, $6,000)

1993: "Making Mineralogy Fun and Interesting." UND Office of Instructional Development ($883)

1993: Travel grant to Geological Society of America Meeting. UND Faculty Research Committee ($320)

1992: "The boundary between the Flin Flon volcanic belt and the Kisseynew gneiss terrane, northern Saskatchewan." UND Faculty Research Committee ($800)

1991: "Glennie-Kisseynew P-T Studies." Saskatchewan Geological Survey ($6,000)

1990: Travel grant to GSA. UND Faculty Research Committee ($900)

1990: NATO/NSF Senior Scientist Fellowship ($20,000)

1990: Faculty Developmental Leave, University of North Dakota ($16,000)

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