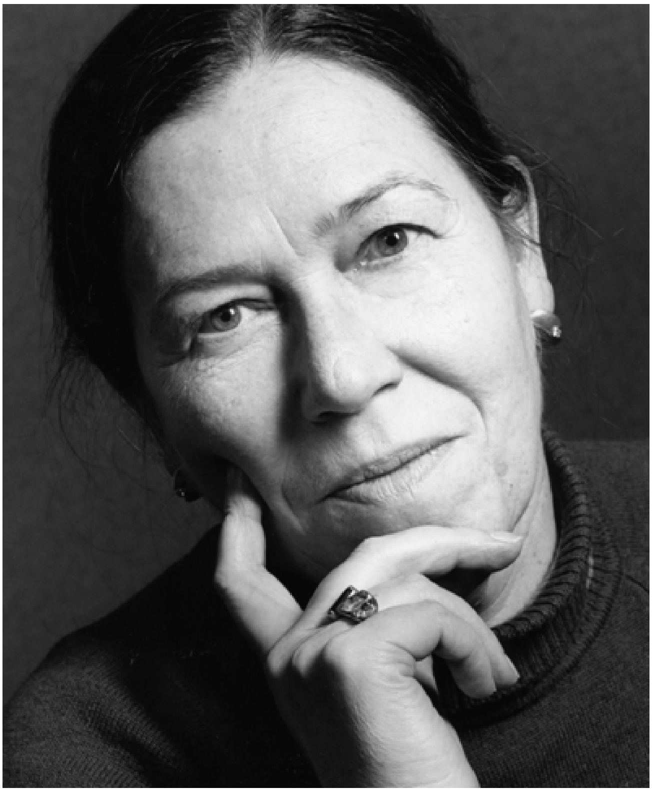
By David Lees, June 2002

Postscript, 2003 to 2007 by David Lees

The Chinese translation by Prof. Dr. Tangfu Xiao and the support by Prof. Jayanta Guha from University of Quebec at Chicoutimi, his Ph.D. supervisor, are gratefully acknowledged.

Margarete Kalin
September 2012



Margarete Kalin, President of Boojum

Preface
序言

Life is a series of milestones. Some pass unnoticed, especially in business where time to reflect is a treasure we often do not have. The reflections in this story about 20 years of Boojum Research Ltd. are an exception. When Allen Yen and I incorporated Boojum it was to engage in two distinct fields of research and development; "systems and subsystems in communication, remote sensing, navigation detection" and "the analysis and modelling of physical and chemical properties of mine wastes and their ecological development and management".

生活是一个又一个的里程碑,有些总在不经意间飞驰而过，来不及回味,尤其是商业事物，我们往往没有时间去好好回味。幸运的是，布杰慕研究有限公司 20 年发展历程在本书中得到了很好的展现。当年艾

伦·颜（颜瑞麟，世界工程学界超长基干理论的创立者）和我成立布杰慕研究公司时，我们致力于两个截然不同领域的研发：“通信、遥感、导航检测系统和子系统”与“矿山废弃物的物理化学特性分析与建模及其生态修复治理”。

Boojum’s first contract was to address a component of a prototype geographical positioning system, which in those days seemed like an idea out of science fiction. We didn’t stay in the field for long but we helped to launch it and today ‘GPS’ is both a household term and the basis of an expanding technology. I wish I could say the same for Boojum’s other interest, the ecological restoration of mine sites and mine wastes.

布杰慕研究公司接到的第一份研发合同涉及地理定位系统原型(GPS)的部分开拓性研发，这在当时看来比科幻小说还离谱。虽然我们在该领域的研究没有持续太久，但我们的原创性研发工作极大地推动了 GPS 的发展。如今，GPS 已经家喻户晓，并成为很多相关信息技术发展的基石，我们为之感到自豪。对于布杰慕研究公司另一研究领域—矿山环境和矿山废弃物的生态修复，我希望也能说出同样引以为豪的话。

Twenty years later, society has begun to raise urgent questions about the environmental impact of mining, but regrettably there are all too few of us pursuing sustainable solutions. In communicating the story of our 20 years, I hope to suggest not that solutions are easy to come by – and they never are – but that solutions do exist and that they can be discovered through perseverance, faith in the restorative powers of nature, and the application of Ecological Engineering.

20 年后，人们开始日益关注矿业开采所造成的环境影响问题。但遗憾的是，追求矿业环境污染治理的可持续解决方案的人太少了。我希望通过展示我们研究公司 20 年的发展历程，让大家明白，可持续的解决方案虽然不能信手拈来（事实上它们确实来之不易），但它们确实存在，发现它们的过程是一个坚持不懈、乐此不疲的过程，需要我们对大自然自身修复能力充满信心，需要对生态工程应用充满信心。

Throughout the past 20 years I was often reminded of the KISS principle – keep it simple, stupid - to which the ecological development of waste management areas does not always adhere. And neither, alas, do my efforts in communicating its characteristics. That is the reason that this story is not written by me. Thank you David.

纵观过去的 20 年，我常常想起的 KISS（Keep It Simple & Stupid）原则—即简单就是美，然而这一原则往往并没有在矿山废弃物管理领域的生态修复实践上得到很好的坚持和应用。在宣传生态修复理念特征的努力过程中，我也没能很好地做到这一点。因此，这也正是布杰慕研究公司发展历史不是由我而是由大卫·利斯来写的原因。谢谢你，大卫！

One decade after Boojum's 20^{th} birthday when the company's history was documented, I am pleased to allow us to bring our knowhow to Institute of Geochemistry of the Chinese Academy of Sciences. It is a great honor. Since that time considerable progress has been made. In April 2010, myself and my colleague Carlos Paulo were invited by Prof. Tangfu Xiao of the Institute of Geochemistry to give lectures in Beijing and Guiyang to audiences of scientists, graduate students, and government officials. We recognized the foresight in understanding the fundamentals of eco-remediation. It was my second visit to China, the country of birth of my late husband of Prof. Jui Lin (Allen) Yen, in 2000, 10 years later. I was amazed at the rapid progress of China and especially at the excellence of Chinese scientists. In August 2012, I was greatly honoured to receive the scholarship of the High-end Foreign Experts Recruitment Program funded by the State Administration of Foreign Experts Affairs (SAFEA) of China. I humbly accept this privilege along with the Boojum team. We promise to give our very best to Prof. Tangfu Xiao and his team to facilitate the application of sustainable decommissioning solutions to mine waste and water management in the Guizhou Province.

本书编写于布杰慕研究公司 20 周年庆典之际。我很高兴能在十年后与中国科学院地球化学研究所开展矿山环境生态修复技术的交流，这是一个极大的荣誉。从那时起，我们的合作交流取得了良好进展。2010 年 4 月，我和我的同事卡洛斯·保罗受中国科学院地球化学研究所肖唐付教授的邀请去北京和贵阳讲学，与中国科学家、研究生和政府官员广泛交流。我们确信这对于深入理解生态修复的本质具有深远的意义。那是我 2000 年后时隔 10 年第二次访问中国。中国是我已故丈夫艾伦·颜（颜瑞麟）的故乡。我惊讶于中国的快速发展，尤其是中国科学家们出色的研究业绩。2012 年 8 月，我十分荣幸地获得中国国家外国专家局高端外国专家项目的资助而再次赴中国开展合作研究。这是我和布杰慕研究团队的荣誉。我将与肖唐付教授及其研究团队一起，致力

于贵州省硫化物矿山废渣及酸性废水生态修复治理的可持续解决方案的研究及示范。

I gratefully acknowledge the support from China's SAFEA, the Environmental Protection Department of Guizhou and Nature Wise & Two Lakes Foundation of Guiyang. In sharing the Boojum history with my Chinese colleagues at the Institute of Geochemistry and all agencies, I trust and sincerely hope that together further progress in eco-remediation of mine waste and water will take place, to the benefit of all people in China, the birthplace of Ecological Engineering at the Chinese Academy of Sciences in Beijing.

在此，我衷心感谢中国国家外国专家局、贵州省环境保护厅和贵阳市两湖一库环境保护基金会对我们合作研究的大力支持。我希望中国科学院地球化学研究所的科学家以及各界人士能与我一起分享布杰慕研究公司成长的历程。"生态工程"理论的发源地是中国，是由中国科学院的科学家提出和创建的。因此，我确信并真诚希望，我们开展的矿山废渣及废水生态修复治理的合作研究将取得新的成就，造福于中国人民。

Margarete Kalin
玛格丽特·卡琳

When Margarete asked me why I accepted this assignment, I told her it was because it was a good story, an answer that I think surprised her. But good stories are the currency of writers and they're hard to find. They contain heroes and dragons and quests of great moral purpose and desperate importance. And all those elements – even the fire-breathing dragon smouldering on a mountain of tailings – are contained in the history of Boojum. It has always been a small company, but for 20 years it has been trying to make a large difference.

玛格丽特问我为什么愿意接受写这个故事，我告诉她：因为这是一个很好的故事。我觉得对于我的这个回答，她感到惊讶。但好的故事确实是作家可遇不可求的财富，它们包括好人、坏人以及好人对于崇高道德目标的追求及其举足轻重的影响。所有这些，甚至包括火舌巨焰的"恶龙"对尾矿山的吞袭，都包含在布杰慕研究公司的发展历程中。布杰慕一直是一家小公司，但是 20 年来一直在做大事。

If that good story is not always apparent in the words that follow it is entirely the fault of the writer. Limitations of time and space meant that the sheer hard work and incremental discoveries that built Boojum's ecological toolkit could not be fully described here. And many voices that should have been heard and reported were not. But Boojum's history is a work in progress and so too is this account of it.

如果如此完美素材没有在本书中得到很好地呈现，那这完全是作者的过错。囿于时间和篇幅，布杰慕研究公司所有艰苦卓绝的工作、接连不断的成果，以及继此形成的布杰慕公司发展的理念体系,不能在此一一叙述。除此之外，许多本应听到和转述的声音也没能一一记录。但无论如何，布杰慕研究公司的发展将一如既往，她的发展历史也将更加丰富和完美。

David Lees, Scientific journalist

大卫·利斯，科学记者

Contents

Homecoming

In the distance, from the crest of a bridge over the Rhine, Margarete Kalin glimpsed the tops of skyscrapers in Dusseldorf. Kalin wasn't particularly happy to be in the car although it was beautiful crisp September morning in 1997. For one thing, she was sick of driving. A few days earlier, she had arrived in Moers, near the Belgian border, picked up Tante Annie, and then drove to Switzerland where Kalin's mother was in a nursing home. Kalin walked outside while the two old friends visited, perhaps for the last time. Then she took Tante Annie home and now was starting out again, heading east to Chemnitz near Germany's far border with the Czech Republic. This would not only be a journey from the prosperous west to the indigent east but a journey into Kalin's own past.

The first time Alex Jakubick, a section head with Wismut GmbH invited her to a wetlands workshop in Chemnitz, she turned him down flat. This was in spite of the fact that the invitation implied a promise of work in the future. Until the reunification of Germany in 1989, Wismut had been the largest uranium miner in the Soviet Bloc. But the mines were all closed now and Wismut had a new role and identity cleaning up the wastes from its operations. For almost two decades, mostly in Canada, Kalin had been doing the same thing, building treatment systems that relied on biology to restore the chemical balance of mine-site run-off. She was recognized internationally for applying the principles of a discipline known as Ecological Engineering to the remediation of mine sites. And the idea was finally catching on. So she told Jakubick that the last thing she needed was a new project in Germany.

But every morning when Kalin got to her offices on Queen Street in Toronto, messages would be waiting for her from Jakubick. And then he would call again. She should really come over, he said; Wismut GmbH was in charge of the largest mine site remediation project in the world. In one of its many projects the firm was designing a small, pilot wetland, following the very principles that she advocated for so long. If it worked it could lead to many more full-scale systems. She owed it to herself, he said, to look at the plans at the workshop.

Germany had a big problem. After the reunification came the grim recognition that the 40-year regime of the German Democratic Republic, in pursuit of productivity at any cost, had created an ecological nightmare. Industry in the east had relied almost exclusively on local supplies of soft coal, heavily laden with sulphur and burned it without scrubbers making the GDR the largest per capita producer of air-borne sulphur in the world. And a huge chemical industry had randomly dumped its toxic wastes into streams, canals and an estimated 15,000 waste dumps, most of them unmarked and most of them leaking. In one town, sixty per cent of the children suffered respiratory problems; in another, children were a half-inch shorter than the national average.

But the major environmental problem in the east was created by the uranium industry. By western standards the low-grade uranium ores in the GDR were hardly worth mining, but they contained the largest deposits of uranium available to the Soviet Bloc; moreover, economics didn't really count since for years the Russians simply claimed the uranium as war reparation. So from 1946 to 1990 the GDR was the world's third largest producer of uranium ore after Canada and the United States. And given the low grade of the ore, it was probably the world's largest producer of radioactive waste rock and mill tailings. They covered a total area of 161 square kilometres and were a constant source of radon, radioactive dust, and toxic run-off. Unlike the uranium mines in United States and Canada, typically located on distant mountainsides or in boreal forests, the GDR mines, and their waste piles, were in populated areas.

By noon, traveling at the unlimited speeds of the autobahn, Kalin had crossed the Lahn valley, and was into the upland forests of the German heartland; castles clinging to distant hillsides reminded her that she was in the land of the Brothers Grimm. She had first noticed 'the Germans' in 1994 when they began showing up at land reclamation conferences and symposiums, asking questions from the floor and hanging around the consultant's booths. The German government had committed 13 billion Deutschmarks to the clean up but money wasn't enough. In the German east, no one had any experience meeting tough regulatory standards; in the German west there were no uranium mines and hence no expertise in uranium waste disposal. So the government had gone shopping for experts and inevitably, had run into Kalin.

The first offer Kalin got from Germany was to serve as a consultant to the Treuhandgesellschaft, a German environmental agency. Kalin said 'no'. Paradoxical as it might seem, there was too much money flying around. The kind of passive solutions she advocated were low-budget, innovative answers to specific problems, and it seemed to her that the Germans were still in a phase she had seen before in many mining companies. They were still looking for an instant fix to their environmental problems, engineered solutions that relied more heavily on concrete and chemicals than innovation.

And then Jakubick had started to call. The problem with conventional treatment plants for mining waste, as the Germans were beginning to experience, is that they have to be maintained forever. So Wismut's engineers were designing a passive treatment system, a small-scale system to determine the effectiveness of bacteria and cattails at neutralizing water and re-mineralizing the metals. The advantage of such a system, if it worked, is that once established it would be self-maintaining. And since Kalin was a leading authority on such systems, Jakubick wanted her to attend a workshop at Chemnitz to exchange ideas on how such systems should be built.

She finally relented, worn down by Jakubick's infectious enthusiasm for the project. She was going to be in Germany anyway to attend other meetings and to take Tante Annie to visit with her mother. Night was falling by the time Kalin sped across the border between Hessen and Thuringia and past the wide clearing in the forests where the

Iron Curtain had once stood. The truth was, she had other, more complicated reasons for not going to the workshop. She was the child of refugees from East Germany and had been a refugee herself and she knew that in the GDR families that fled had been considered traitors. It was a slur that she wasn't entirely sure she was ready to forgive.

A road sign flashed past in the gathering dark of the evening. Anstadt; her grandmother had lived there – not to mention Bach – and Kalin had often visited on her bicycle; Erfurt where her father took her to a church where Luther had had once given a sermon; Eisenach where she and her father sat in an airport in 1960 waiting for a flight to East Berlin where they would slip over the border to rejoin her mother and sister and brother. Kalin realized, with a shock, that she had come home.

Early Days

Margarete Marie Seidenfaden was born in 1947 in the village of Elxleben in the province of Thuringen. Brigitte, her mother, was a teacher and Erich, her father, was a Lutheran pastor who administered to the spiritual and emotional needs of the farm families in the district. In the years after World War II these were great. But while most families had lost sons or fathers there was little industry in the district so it emerged from the war relatively unscathed. For young Margarete, it was a place of farms and gardens and rolling hills. But she never forgot the image of Russian tanks on maneuvers carelessly rolling through an apple orchard, crushing trees in flower.

There was no uranium near Elxleben, but when farmland further east was dug up to make way for pits and mines or buried beneath tailing dumps, the farmers in the area were expected to make up for lost production and to do so by merging their holdings into vast agricultural collectives. The farmers resisted and were aided and abetted by Pastor Seidenfaden. When authorities demanded that he travel village-to-village, extolling collectivism through a car-mounted loudspeaker he refused. Brigitte decided that the entire family was now in danger and that the time had come to flee to the west. The family escaped to West Berlin and from there, by way of refugee camps, to Switzerland. They had barely settled in the alpine village of Guttanen, in the shadow of the Grimsel Pass when Erich Seidenfaden died. Margarete was thirteen.


Family, 1960

"I never asked my father a question that he didn't answer," she recalls. "If I asked him how do the clouds work, why is the sun shining, why are things growing, he knew. Where do the rocks come form, what are metals, why do people want gold? My father knew everything."

She inherited from her father an intense curiosity about the natural world. But while the child desperately wanted to learn more, Swiss authorities thought she was an unlikely candidate for university. She was slightly dyslexic – like Einstein, she says - and her education in East Germany while strong on dogma was deficient in subjects more important in the West. So she was routed instead to a Swiss trade school to be trained as an agricultural biological technician. She then applied to Geigy, the Swiss pharmaceutical giant hoping to be apprenticed in its herbicide/pesticide division. The company was glad to get her, but the recruiting officer suggested she'd be happier working with other girls, formulating colours for paint. Testing herbicides and pesticides was man's work.

"I said that's too bad because I don't want to work with colors," Kalin recalls. "And I don't want to test pharmaceuticals on rabbits and apes. I want to design herbicides and pesticides."

So with brash confidence, the 16-year-old phoned the director of the pesticide division and asked him what he had against women. The policy was news to him and he reversed it and for the first time, half the six new apprentices in the division were female. Margarete was sure he would be pleased with his decision since she intended to show the company a better way to kill bugs, using the natural forces of nature instead of chemicals. As it happened, he wasn't. She finished her apprenticeship but left the company and got a job as a technician in a genetics lab at the Swiss Federal Institute of Technology, a teaching facility in Zurich inducing mutations with X-rays in fruit flies.

"I went to my boss and said I'll make you a deal. I'll do my work as a technician in the evenings so I can go to lectures during the day." She didn't write exams but listened and learned from lectures on plant physiology, zoology and genetics.

In Zurich, she met and married Max Kalin, a geology student who was writing his PhD thesis on the push moraines on Axel Heiberg Island. In 1972, when Max was hired as an assistant professor at the University of Waterloo, the couple immigrated to Canada. Margarete finally fulfilled her yearning for higher education by gaining admission to Waterloo as a mature student. She registered for courses in the sciences, but because of her limited English inadvertently enrolled in Arts. A few weeks into the semester she got a call from an undergraduate-dean. They made a deal. If she passed her mid-term exams – which she managed to do - he would let her stay in the Sciences. In the confusion, no one noticed that she had registered exclusively in second year courses.

Two years later Max got a job at the University of Toronto. Margarete transferred with him and completed her fourth-year courses. The marriage fell apart but Margarete kept her married name and applied to the masters program in entomology at Berkley and Cornell. Both seemed ready to accept her. But then the Toronto registrar called to say there was a problem; she didn't seem to have any first year credits.

"Let's make a deal,"she said.

So four professors were drafted – not all of them willingly – to gave her spontaneous, oral exams. She convinced all of them that she would have passed their first-year courses if she had only taken them, they gave her the credits she needed and the university began to process her degree. But by this time the summer had slipped away, the deadline for admissions elsewhere had passed, so she made a deal with the registrar of graduate studies who admitted her late to the masters programs at the University of Toronto. She graduated in 1977; the panel that reviewed her thesis, which linked the social behavior of saw flies to their mortality rates was no doubt impressed by the fact that a summary of it had already been published in the journal *Nature*.

She planned to go back to Switzerland to get a doctorate in entomology. But by this time she had met physicist Allen Yen and she'd always had a weakness for brilliant men. Yen was born in China in 1925 and had been a professor in the Department of Electrical Engineering since 1952. He was a generalist in a field that had begun to fragment into the disparate fields of computers, electromagnetics, and communications and radio astronomy; in other words, he was resident on the ground floor of them all. A colleague later said of him that he led the department out of the era of vacuum tubes and into digital electronics. He was a co-recipient of the Rumford Medal awarded by the American Academy of Arts and Sciences for the contributions he made to Very Long Baseline Interferometry, a technique that revolutionized radio astronomy. But his abiding passion, he told Kalin, was for a new technology that would bounce radio waves off satellites and into


Margarete and Allan at Niagara Falls, 1979

receivers that could then calculate their exact location. If she possessed such a receiver, he told her, it would tell him exactly where she was on the face of the earth, even if she was back in Switzerland. But it wouldn't do either of them any good.

So Kalin agreed to stay in Canada and began to look for work. She found a short term job setting up a research library for Morton Dodds Partners, which did hydrology work for mining companies; among other tasks it predicted the flow of ground water that might carry contaminants from mine sites. She was still setting up the library when the company went after a contract to repair a retaining dam holding back the tailings at uranium mine in Eastern Ontario.

Just as ore from East Germany had sustained the Russian nuclear build-up, ores from 12 Ontario mines had helped build up the American arsenal. By this time more than 140 million tonnes of mildly radioactive tailings had accumulated in the bush near Madawaska and Elliot Lake. Ontario Hydro was planning a major expansion of its nuclear capability and in the ensuing public debate the remote tailing sites were attracting attention. So the Atomic Energy Control Board was putting pressure on the mining companies to cover their wastes with grass to prevent the wind-blown dispersal of dust, and to ensure that they were tightly contained. When the tailings site at Madawaska began to leak, it insisted that the owners of the site, the Madawaska Mining Company do something about it.

So Morton Dodds was trying to get the job. To demonstrate the thoroughness with which it viewed the problem, it asked Kalin to review the literature and write something 'environmental' to go into its submission. She thought the task would be easy. As it turned out, it was impossible to find out if anything grew on tailing sites, at least, by sitting in a library. While botanical journals obsessed over the hierarchy of plants growing in idealized, climax communities, they showed no interest at all in the weeds and fungi that grew in the alleyways and garbage piles of industry.


Lichen on Madawaska tailings

The Tailings Trail

Kalin did much of her research in the library at the Institute of Environmental Studies (IES) at the University of Toronto. The associate director of the institute was Pamela Stokes, an expert on the environmental dispersal of heavy metals. Inevitably, the two women ran into each other. Stokes asked Kalin what she was doing and Kalin described her assignment and the gap she had discovered in the literature; no one seemed to know what if anything was growing on uranium wastes.

The two women agreed that if there was ever a premise for a successful research grant this was it. The scandal over chemical dumping at Love Canal had just erupted raising concern about industrial dumps in general, and while the tailings dumps were remote, every Canadian who read a newspaper knew about bio-magnification; in the climate of the times it didn't seem farfetched to believe that plants on the tailing sites might be concentrating radionuclides in their seeds, berries and foliage, and that these were getting into the food chain. A few weeks later Stokes phoned Kalin to say that the Ontario Lottery Corporation would pay for students to look at a uranium tailings site to find out what was growing there. Did Kalin want to head up the study? By this time Kalin was out of work, having finished the contract with Morton Dodds, and happily accepted.

In the summer of 1978, Kalin and four students arrived at a 20-hectare tailings site about eight kilometres south of Bancroft. Owned by the Madawaska Mining Company, the nearby mill and mine had been in operation, albeit sporadically, since 1957 supplying uranium oxides, known in the trade as yellowcake, to Eldorado Nuclear Ltd. On site, the ore was initially ground in steel cones and then rolled in drums with pebbles to reduce it to the consistency of coarse sand; this exposed the uranium so it could be dissolved in an aerated bath of sulphuric acid and sodium chlorate. The process yielded less than two pounds of uranium per tonne of rock so the primary product of the Bancroft mill was uranium tailings. These were pumped as liquid slurry to the disposal site, a


Operating tailings pond

large pond known locally as Plunket Lake. But the pond had long since been buried in a 14-foot pile of waste that was now held in place by dams made of waste rock, the overburden from the mine.

To cut down on windblown dust, the company had cultivated, fertilized and seeded most of the site with grass, trefoil, oats and clover but the crop had failed. Kalin wasn't sure, looking at the few straggling sprouts of trefoil that survived, if alkalinity had killed the crop, or the physical conditions of the site; for all intents and purposes the tailings were a micro-desert that baked in the sun, flooded in the rain and heaved in the frost. It was a formidable terrain for anything with roots.

But a variety of plants had taken hold on the oldest parts of the site that had been undisturbed for up to 17 years. Weeds, brush, birch, poplars and willows grew in a moist drainage trench and in the humus that had been trapped by an internal dam. And even in the open stretches fungi and mosses had taken root in the deep cracks that latticed the ground or wherever a log or rock cast a shadow. Wild rye, dog weed, dogwood, honeysuckles and balsams had invaded a low-lying patch of growth. Strawberries grew nearby. In the damp ground, around two small puddles, was a thin stand of Typha angustifolia, the common cattail. Kalin had tested the pH all over the site typically recording readings of 8.3 to 8.7. But around the cattail roots it was 6 to 7. So had cattail seeds managed to find a patch of neutral ground? Or were the cattails changing the soil pH to suit their own needs? Kalin searched the literature but found nothing.

Kalin's students identified more than 68 species of plants growing on the site as well as three mosses and four lichens. Nowhere was the growth luxuriant; the trees were stunted, and some species were represented by only a single plant. But in general, the indigenous growth was doing better on its own, without help, than the domestic grasses planted by the company. There is nothing in Kalin's report to the Ontario Ministry of the Environment about the theoretical environmental menace posed by indigenous plants. But she mused


Madawaska tailings vegetation

"It would not be difficult, to select and recommend native plant species for revegetation program".

News of the research project spread rapidly through the small, closed world of nuclear regulators. Ken Hare, director of the IES, sent a copy of it, and a glowing recommendation to Arthur Porter, chairman of the Royal Commission on Electric Power Planning. Porter wrote to M. Benoit Jean, director, of the Programs Branch for Supply and Services Canada, recommending that the IES be funded to do more work. "After meeting with Margarete Kalin who is the proposed project leader, I am convinced that she has outstanding qualifications for this task and her enthusiasm is boundless." Hare urged her to expand the study to include other inactive tailings sites in the Bancroft region and to sites in Elliot Lakes where the soils were acidic.

But while Kalin's academic background had taught her how to generate funding for research contracts, nothing had prepared her for the parallel universe of the mining industry. She arrived, in the fall of 1978 at the gatehouse of Denison Mines in Elliot Lake for a pre-arranged meeting with Steven Harapiak, the vice-president of uranium operations to arrange the terms and conditions by which she and her students would gain access, the next summer, to the company's tailings. She got there punctually at noon. The gatehouse reported her arrival but Harapiak was apparently busy. Kalin waited. She was still there when the day shift went home. And was there again when it returned the next morning. On the afternoon of the second day, Chuck Chakravatti, Denison's senior environmental engineer finally showed up, gave her a hard hat and took her to the mine offices. Harapniak ranted at her at length. The last academic given access to the property, he complained, had brought a CBC camera crew with him. When he finally asked if she had anything to say for herself, she told him he might have offered her a chair.

Her defiance must have appealed to Harpaiak, because he turned her over to Chakravatti who gave her a tour of the company's waste sites. Denison had also tried to grow grasses on its sites. Kalin wasn't surprised to see that the domestic crop had died but that many of the weedy species she had seen at Madawaska, especially cattails, had taken hold. By this time she thought she understood the phenomena. She had discovered from the literature that cattails extrude polysaccharides into their rhizosphere, the soil around their roots, and had concluded that these served as buffers, taking up hydroxyl ions in alkaline soils, or hydrogen ions in acid soils, which in either case produced the neutral pH environment that the plant needed to take up nutrients. This, in turn, caused heavy metals to precipitate out of solution, binding them into the tailings.

Chakravatti was intrigued by the concept. The Canadian mining industry, in the early 1980s, had just run into an environmental problem that seemed next to unsolvable; it had always been there, but in the past was easy to ignore. Most minerals mined in Canada, in fact in the world, come from ores that are also laden with sulphides, the reduced form of sulphur. The same processes that expose the minerals, first grinding and then a series of chemical baths, also expose the sulphides. Some of these go up smelter smokestacks, but most are separated out at the mine site mill and pumped as slurry into a tailings pond. There they combine with water and oxygen to form sulphuric acid, which dissolves more minerals and further breaks down the tailings. The resulting run-off is known as Acid Mine Drainage (AMD) or Acid Rock Drainage if it comes from a waste rock pile, the mine gangue too deficient in minerals to be worth milling. But like the tailings, the waste rock contains enough metals to make the run-off not only acidic, but also toxic.

And that's only the start of the problem. The tailings pile provides

an ideal environment for a variety of bacteria that derive energy from the oxidation of iron sulphide minerals; the best known of these is Thiobacillus ferrooxidans, which can accelerate the breakdown of pyrite by a factor of millions. T. ferrooxidans thrives not only in the finely ground tailings and waste rock, but on the exposed rock face of underground workings and in pits. So for all intents and purposes old mines are perpetual pollution machines.

Traditionally, the mining industry had ignored the problem, but now under pressure from regulators, it had begun the search for solutions. No one knew how to stop the run-off, once it had begun, so the only available strategy, Chakravatti told Kalin, was to treat it with limestone to counteract acidity and force the precipitation of dissolved metals. But this merely creates a new problem in the form of the resulting lime sludge, now laced with heavy metals, which typically is dumped back onto the tailings pile. Sooner or later, the metals are bound to end up back at the treatment plant. So mining companies were waking up to the reality that they could be operating treatment plants, at the sites of old, worked out mines, in perpetuity. Moreover, limestone isn't cheap and it never seems to be available where you need it. If Kalin wanted to do something for the industry, Chakravatti said, she should stop the lime trucks.

In the summers of 1980, 1981 and 1982, supported by grants from AECB, EMR and Environment Canada, Kalin and her students camped out at 15 tailing sites at Bancroft and at Elliot Lake and Uranium City, Saskatchewan. The mandate of the studies was still the same, to evaluate the potential menace of bio-magnified radionuclides but Kalin was already convinced that indigenous plants tend not to take up radioactive elements; the most radioactive plant that the study found was a tree growing miles away from any tailings. Moreover, a detailed study of Lead-210 uptake by cattails, Kalin and H. D. Sharma, a radiochemist at the University of Waterloo, showed that plants stored the element in their roots, effectively taking it out of circulation. Kalin thought the AECB and her colleagues would be pleased, but in the confrontational climate of the times, the paper suggested to many that she had become 'pro-nuke', a lackey of the uranium industry.

Kalin's focus on potential solutions rather than problems increasingly isolated her at the IES. She found a kindred spirit however in the fall of 1982, when she was approached by Martin Smith, a recent U. of T. science graduate who had just returned from a summer job in the high Arctic where he had grown an experimental crop of potatoes in a green- house. Smith was raised on a pig, corn and soybean farm in southwestern

Martin 1983

Ontario, and had combined a farmer's pragmatism with a degree in botany, which gave him… well, as it turned out, not very much.

Botany in those days, he muses, was a purely academic pursuit with little application in the real world. When he complained to a friend that there was no market for his varied skills, she told him about 'an eccentric, rich woman' at the IES who was looking for researchers to evaluate plants growing on mine tailings. When he approached Kalin she asked him the minimum amount of money he needed for survival. He said $400 a month. She hired him to count and determine the age of trees on a site at Elliot Lake. Smith immediately picked up on the tension at the IES.

"Margarete didn't have a Ph.D.", he recalled, "and was supposed to be under the wing of other professors at the institute. But she didn't like being supervised or lorded-over by anyone. So she pushed back until they thought 'to hell with her'. And that had its advantages because it gave her tremendous independence and allowed her to make a name for herself but it created tension. And she got more contracts and bigger grants than anyone else so she was a bit of a star at the institute. But that also made her a source of envy."

The beginning of the end at the IES began one day in 1984 when Kalin came to work and discovered that her part-time secretary had been fired; the official explanation was that the university was cutting back services to research associates. Kalin was still committed to completing several reports, including an environmental survey of mine sites in the Northwest Territories and the Yukon, but the focus of her efforts now shifted to Boojum Research Limited, which she and Allen Yen had founded in 1982 to pursue his research interests developing a prototype for a geographic positioning system; for the past year she had been managing the company's books. Since she was too headstrong to work with academics, he told her, she should use the company as he did, as a platform for her own research interests.

Yen had named the company after the mythical beast described by Lewis Carroll in the whimsical poem The Hunting of the Snark. A team of misbegotten adventurers pursues the Snark, although none of them have ever seen it. One, however, has been warned by his uncle…

"You may seek it with thimbles -- and seek it with care;
You may hunt it with forks and hope;
You may threaten its life with a railway-share;
You may charm it with smiles and soap – "

"But oh, beamish nephew, beware of the day,
If your Snark be a Boojum! For then
You will softly and suddenly vanish away,
And never be met with again!"

The poem suggested to Yen the persistent dilemma of scientific research; if your research is not focused it can swallow you. On the other hand, if you're lucky, you might find one thing while you're looking for another. The poem reminded Kalin of her own research into tailings and she was tempted to join Yen full time at Boojum. But while it was one thing to observe the effect of cattails on soil pH, it was another to turn biology into a saleable product. And Chakravatti had always told her that the real problem was not on the land but in the water. She promised herself that if she ever found anything that would clean up water, she'd go into business for herself.

O Chara Mia

In 1983 Kalin gave a seminar at the IES about her ongoing surveys of tailings vegetation when she was approached by Professor Dr. Takashi Sawa, a professor of botany at the university and one of the four professors who had presided over her first-year make-up exams. Sawa specialized in the study of Charophytes, a family of aquatic algae. In his work, he often stained parts of the Chara cells with uranium-based dyes to enhance the image under an electron microscope. He had noticed that Chara was an absolute magnet for uranium. Any imperceptible trace of the stain left on his slides or equipment invariably attached itself to the dried strands of algae. The algae's affinity for uranium was a trait, it occurred to him, that might make it useful as an air filter in uranium mines. Since Kalin was in touch with executives in the uranium industry, he wondered if she would make inquiries on his behalf.

Kalin said she'd suggest the idea to Chakravatti at Denison but then asked Sawa if Chara grew in water that was alkaline or acid. Alkaline, he replied. Chakravatti asked exactly the same question when she called him. There was no need in the industry for a new air filter he said… and no use for it as a living filter in the ponds at Elliot Lake since most were acidic. But not the water coming out of the treatment plants, Kalin reminded him, which was alkaline having been treated with lime. Moreover, the treatment process left trace amounts of uranium and radium in the water, sometimes in excess of regulatory standards. Chara could be grown downstream of the treatment plants and would polish the water to bring the contaminants into line. Chakravatti was sold. He said he would call Rio Algom, Denison's principle competitor, which might co-sponsor a research project.

While Chakravatti looked for money Kalin delegated the task of finding out more about Chara to Smith, a task that would preoccupy him for the next decade. Chara, he discovered, is indigenous on every continent but Antarctica and grows wherever shallow water and limestone create conditions to its liking. Most algae are free floating; taking nutrients directly from the water but Chara is like a fine grass, often visible as a pale green meadow on the bottom of ponds. The stem of each plant is only a single-cell thick but the cells can be up to 25 centimetres long making them among the largest cells in the plant kingdom.

Chara is commonly known as stonewort because of its ability to extract calcium from the water to build limestone sheaths around its stem. This, in turn, was a product of Chara's evolutionary specialty, its


Chara

ability to grow in alkaline waters. At pH 9 Chara has the pond to itself, since carbon in such waters takes the form of bicarbonates that cannot be absorbed by plants. But evolution had taught Chara the trick of splitting molecules of water into their component parts, an ion of hydrogen and a hydroxyl ion, a hydrogen atom still linked to an atom of oxygen. It extrudes the hydroxyl through one portion of its cell wall, making the water there so alkaline that calcium – as well as copper, nickel and radioactive elements - precipitate out forming a stony sheath around the stem. Through another portion it extrudes the hydrogen, lowering the pH, which causes the bicarbonates in the water to break up, and allowing Chara to grab the liberated carbon dioxide.

By the spring of 1984, Denison and Rio Algom had come up with $5000 to pay Kalin to transplant Chara into the run-off waters from its treatment plants and alkaline ponds at Elliot Lake. Professor Sawa had shown Smith that Chara grows wherever still, shallow water sits on limestone, so in May, Kalin and Smith made their first expedition to Elliot Lake by way of Guelph and Manitoulin Island. Wading into ponds along the way, they raked in Chara and dumped it into beer coolers in the back of a rented car. Each night, in the bathtubs of roadside motels they washed the Chara and painfully segregated it into ten clumps each containing 500 strands. Each clump was supposed to go into a box, mesh stretched over a cast iron frame, made to Kalin's specifications at Denison's workshops. In fact, only eight boxes were ready, and the seeding of two ponds took place on a subsequent trip.

The boxes were a cubic metre. The size of them reflected the confidence of Smith and Kalin that by the end of the summer they would be packed with green thriving Chara. But each box, containing a few centigrams of Chara, weighed about 100 kilograms. They were, to put it mildly, hard to handle in an aluminium rowboat. Smith manned the oars, guiding the boat to the middle of the tailing ponds, while Kalin balanced the boxes on the bow and, in spite of his repeated warnings, stood up to shove them over the side. Smith's problem, Kalin recalls, was that he couldn't swim. Smith says he could swim all right; he just didn't want to do it in radioactive water.

On June 22, Smith and Kalin were back on the ponds, hauling in the boxes, which had become even heavier, not with Chara, but with mud and debris. Here and there a few green whorls were evident, but for the most part, all that remained of the plant were clumps of black, disintegrating goo. In an intermediary report to her sponsors,


Chara Harvest

Kalin noted they had experienced 'negative growth'. But there were two notable and exciting exceptions. One of the boxes, finished late, had been dropped only nine days previously into Nordic Lake. Since then the Chara had increased its biomass by 36 per cent. Another steel box had been dropped near the outlet of a pipe from the mill at the Pronto Mine and had been all but buried in the slurry. Yet beneath the gunk, 70 per cent of the plants were still alive.

Kalin and Smith had brought a new harvest of Chara with them. They primed the steel boxes again and dropped them back into the water. Four weeks later, most of this crop was dead as well even at Nordic Lake. But at Pronto where the box had been moved further from the outlet ninety per cent of the plants were alive, reason enough, Kalin reported to the companies, to continue the experiment. Moreover, she noted, the National Research Council was funding further research and she had found another client who was interested in the process.

Kalin had known Tom Peters, the agricultural director at INCO since 1982, when he introduced himself to her at the annual meeting of the Canadian Land Reclamation Association (CLRA). Caroline Caza, one of the students who had been with Kalin on the tailings expeditions and who was writing her master's thesis on the growth of poplars on tailings, had just given a talk about her findings. Peters must have been impressed that anyone, outside the industry, was interested in tailings. It was a matter, however, of considerable importance to INCO, which generated 50,000 tons of tailings every day. In the 1950s, visibility in the City of Sudbury, had frequently been nil in the dust storms that blew off the company's sites. INCO tried to seal its tailings beneath asphalt or crushed rock but neither strategy was practical on the soft shifting ground. So Peters had taken on the assignment of getting grass to grow on the sites. He succeeded with the help of prodigious applications of lime and fertilizer.

But as Peters knew, grass didn't stop water and oxygen from percolating down into the tailings and as long as that happened acid run-off would be produced. Moreover, he confided to Kalin, there were some sites that were simply too rough to support domestic crops. Peters and Kalin talked again at the CLRA in 1983, after she presented a paper describing the vigor of cattails on uranium tailings and their ability to adjust the pH of the soil around them. By this time Kalin had become convinced that indigenous species could provide a better ground cover on tailings than domestic crops; moreover they would be vastly cheaper because they would not need perpetual care and maintenance.

In her research, Kalin had come across the work of the American ecologist Howard T. Odum, who in 1962 coined the phrase Ecological Engineering. In Odum's view, natural systems could and should be managed to support humanity. He postulated that ecosystems which had efficiently maintained a balance of energy over thousands of years contained a body of knowledge - if it could only be decoded – that could be applied to agriculture, industry and waste disposal. By understanding the intricate workings of a natural system, it should be possible to manipulate it, adding small amounts of energy at the right time and place, to achieve large benefits. This was Ecological Engineering, the design, construction and management of sustainable ecosystems that would integrate human society with its natural environment for the benefit of both.

Applied to a tailings site, Kalin told Peters, Ecological Engineering suggested that it was foolhardy to chew up the ground with cultivators, uprooting whatever indigenous plants had managed to take hold, simply to establish domestic crops that would hold the ground less well than the plants they had replaced. And do it more cheaply. The idea at the heart of Ecological Engineering was to work with nature, not against it. Peters told her that if she was ever in Sudbury to come by and see him. If she did, he would give her a tour of INCO's tailings.

So in the summer of 1984 on the southbound leg of the Chara express, heading back to Toronto from the Denison ponds, Kalin accepted the invitation. On successive trips, Peters took her out to the Copper Cliff tailings, the world's largest mountain of mine waste, and to the Levack site, a barren wasteland of red, oxidized pyrrhotite. The company still operated a mine at the site, but hauled the ore to mills in Sudbury. So the tailings were all old but had been barely colonized by plants because the last tailings to be dumped on the surface consisted of pyrrhotite, which is even more reactive than pyrite; fresh pyrhottite is so unstable, in fact, that it burns in the rain.

The site covered about 40 hectares lying in a long sloping embankment contained by a ring of dykes. In theory the dykes were impermeable, having been lined with plastic, but the plastic had ruptured and acid water was now getting out. The pyrite below the pyrrhotite had been ground so finely that it had formed a kind of quicksand that made it impossible to get tractors or cultivators on the property, so the chances of growing grass here were nil. Oddly, the extremely acidic site was bisected by an alkaline stream emitted by the old tailings pipe that now delivered mine slimes from the still-operating mine. The slimes contained nitrates from blasting powder, the powdered rock itself, and a considerable amount of lime from the concrete that was constantly being mixed to fill worked-out mine shafts. The mine waters had accumulated in a large pond at the southern corner of the site. Not far from it, an old quarry had filled with acidic run-off from the site. So, in effect, a pond of Drano lay within a few yards of a pond of vinegar.

Apart from an island of trees, still growing on high ground, the site seemed, at first glance, to be completely barren. But it wasn't hopeless, Kalin told Peters. Blue green algae grew in the alkaline pond, a promising indicator that Chara might do well, and cattails were already making inroads along the shore of the pond, along the alkaline stream of mine slimes, and in the almost stagnant waters of an acid creek that meandered across the property. In puddles on the site she found a thick yellow gunk that would prove to be Ulothrix, an alga with an affinity for ferric iron.

Levack, Kalin told Smith, was the worst site she had ever seen. More cheerfully, she told Peters, it was a perfect testing ground for Ecological Engineering.

Peters said if she wanted to conduct a more thorough survey, he might be able to fund a feasibility study. But first she would need the approval of a vice president of operations, a miner of the old school, who it turned out was not warm to the idea of academics roaming the property, never mind females. He told Kalin bluntly that he doubted anything would grow on the site or that it would make a difference if it did. Finally, he asked her how long all this was supposed to take.

"Why don't you call God," Kalin said. "He can give you an answer right now, but I sure can't. That's why we want to do the study."

"I'll give you the $5,000 for your study", he said. And walked out. Years later, he told her that he liked her answer.

Over the winter, while Kalin was writing her first report for INCO, the federal government had begun to fund research, jointly with industry, into the search for solutions to acid mine drainage. Kalin's Levack experiments would be among the first projects the government supported under its new Reactive Acid Tailings program. Kalin proposed a series of experiments; in the alkaline pond, she intended to introduce Chara, and in the acidic waters of the flooded quarry acid-tolerant, aquatic mosses and algae. She would plant cattails wherever there was moisture on the site, and the Ulothrix she had found just off the site, into the meandering acid creek.

By the following summer it had occurred to Kalin that the pH of the Levack site was perfectly balanced, but badly distributed, concentrated into extremes of alkalinity and acidity. Blend them, and the site would be neutral or close enough to it that native plants would rapidly take hold. The most obvious solution was to spread out the flow of mine waters but the pipelines, sprays and drip-systems built by INCO's engineers all clogged. Finally, Smith and a team of INCO summer students built three low dams, like

Hand constructed Dam

overlapping boomerangs, to intercept and disperse the stream. It was the old-fashioned way of doing things, but it was bound to work.

Acid Tests

Word that INCO, Canada's foremost hard-rock miner, had turned over a tailings sites to a woman spread quickly in the small, closed world of Canadian mining. Kalin was an anomaly, Chakravatti observed, and no one knew what to make of her. "She isn't a consultant", he said, "because she doesn't ask for enough money; she's not a scientist because she doesn't work at the university; and she isn't a regulator because she isn't looking for problems." But her exotic stature did her no harm as the industry began to recognize how desperately it needed new answers to old problems. So with the endorsement from INCO, and the promise of grants from the federal government, doors began to open.

The Ontario Ministry of Natural Resources gave her a $15,000 contract to survey the Kam Kotia tailings site, a toxic nightmare bequeathed to Ontario taxpayers by a bankrupt mining company; Kalin felt she had almost secured a contract to clean it up, in partnership with an engineering firm, when the job was cancelled. The Department of Indian and Northern Affairs hired her to analyze data from 21 abandoned mines in the Yukon and the Northwest Territories to determine whether or not they posed an environmental hazard; the work in effect was a golden opportunity to study how ecosystems, left on their own, reacted to mining activities. Almost by default Boojum had become a clearinghouse for tailings-related data; Kalin and Smith had free access to a terrain rarely seen by outsiders.

In the fall of 1984, Bob Michellutti, the environmental director at Falconbridge took her on a tailings tour and listened to her theories of Ecological Engineering. He was impressed by the idea that cattails would root themselves anywhere they found moisture. Enthusiastically he sent out a work crew to dig large potholes in the Fault Lake tailings next to the company's Sudbury smelter.

"It's not quite that simple," Kalin warned him.

"Why not," Michellutti replied. "If it works it works."

Kalin was back in the office the next morning when Miceillutti called.

"You win," he said, good-naturedly. It had rained the night before and the potholes were all burning.

Inevitably, on the conference circuit, Kalin met Ron McCready, a director of Biominet, a network developed by Industry Canada to promote biotechnology and biohyrdometallury. McCready had worked with Denison to develop a system of mining uranium with bacteria, injecting them in a solution of nutrients into the ore, still in the ground, and then pumping the solution back out laden with

Pre-bog acid creek

uranium dissolved by the bacteria. McCready believed you could do almost anything with bacteria, and introduced Kalin to the idea that since bacteria created AMD in the first place, bacteria could also cure it. He put her in touch with Alcan, which was looking for solutions to problems at its bauxite mine at Chicoutimi; its tailings from the operation were heavily contaminated with cyanide. That deal fell through as well, in a disagreement over intellectual property rights, but Kalin found bacteria on the site that were already degrading cyanide. McCready was right, she realized, and began to apply his ideas at Levack.

By the end of the 1986 summer, Boojum's experi-ments at Levack were showing mixed success. The catch basins in the boomerang dams were green with the horsetails, which had seeded themselves, a perfect expression of Ecological Engineering. Moss she had gathered from Falconbridge's Fault Lake site was growing on pyrrhotite albeit with help from urea-based fertilizers, and Chara had taken hold in the alkaline pond in spite of the jolts of acidity that occurred with every heavy rain when it was flooded with acidic run-off; ironically, it was killed when a leaking tanker truck used the pond to get rid of its load of caustic soda.

But the biggest disappoint- ment on the site was the failed restoration of the ketchup-red acid creek that trickled through it. Kalin called it the Pre-Bog Acid Creek in anticipation of the wetland she hoped would one day surround it. At her direction INCO staff had thrown three dams across the stream to create a sequence of small, deep ponds in which she introduced algae and aquatic mosses. Some of these had survived but produced no measurable affect on the quality of the water. Taking to heart McCready's message about bacteria Kalin strung cotton blankets across the ponds to create six deep experimental cells which she packed with peat, sawdust, healthy soil and leaves gathered in the surrounding forest. The results were spectacular. Within two weeks, the water running from the cells was not red but clear, a sure sign that the ferric iron in the water had been reduced to ferrous iron. Bacteria, finding nutrients in the organic matter, and niches in which they could thrive had begun to produce a yellow, sulphur rich precipitate, the first sign that minerals were being taken out of the water. Boojum had hit its first home run.

On the strength of the experiment in Pre-Bog Acid Creek, INCO and Boojum jointly applied for funding from the Mine Environment Neutral Drainage Program, (MEND), a new federal initiative to build and operate a pilot-scale


Pre-bog acid creek after straw

passive treatment system. It would be built not in the bush but at the Copper Cliff site, the centralized depository for all of the company's mines in the Sudbury area. The site was surrounded by a drainage ditch that gathered the run-off into pumping stations, which sent it back to the top of the pile. One of these was the Makela Station, located at the base of the pile. There was room around it, on more or less level ground, to construct six treatment cells.

The Makela cells, each about 1.5 metres deep, 20 metres wide, and ranging in length from 5 to 30 metres were in place by the spring of 1999. The cells were linked to each other and to the drainage ditch by wooden weirs, which were supposed to strictly control the flow of water through into the system. It soon became obvious, however, that ground water was getting in the system as well, which wasn't a problem in itself, but the volume of ground water had to be precisely measured so it could be factored into subsequent calculations. And this took time. And then the sloping banks of the cells, made out of gravel covered with clay, began to slump and had to be rebuilt. By the time that problem was solved, the water had begun to cut a path around the sides of the weirs so plastic pipes had to be installed instead. The net affect of the delays was that no serious Ecological Engineering was done at the site until the spring of 1990.

Kalin's plan was to prime the system with organic matter, which would eventually rot and create sediments. Then she would add cattails and other plants, to provide a continuing supply of organic materials to sustain the bacteria. None of this was possible until the

ARUMators

flow of water was under control but she did manage to install barrels in the cells, packed with alfalfa, flax and potato scraps and flooded with the seepage water. These so-called ARUMators were expected to simulate the performance of the actual cells and in fact, analysis of water samples taken from their cores indicated that the pH was rising, and that anaerobic bacteria were turning sulphates into sulphides.

In the after-glow of the Levack experiments, no one doubted that the system could be made to work. But in retrospect, it would seem to Kalin and Smith, the Makela cells broke all the rules of Ecological Engineering. The nature of the MEND contracts, by which mining companies receive credit – not to mention tax deductions - for their contributions of labor, equipment and materials tend to drive up costs. The budget was so high that it overshadowed every other aspect of the program. One bureaucrat coined the term "Kalin-units" to express the cost of expensive, unwieldy projects.

Floating cattails

Finally, in 1990 Boojum began to add organic amendments to the Makela cells, initially installing internal walls made of bales of flax and alfalfa. In theory water was supposed to flow evenly through the bales, but water has a mind of its own, and quickly cut its own preferred pathways. For two seasons, water poured out of the system exactly as it come in, just as acidic and still laden with trace metals. "We were on the verge of credibility flame-out," Smith concedes.

But work in the lab, and results from the ARUMators all indicated that the system should be working. Finally, looking at the windblown surface of the Makela cells, it occurred to Kalin that the difference between the Makela cells and the stagnant water in Pre-Bog Acid Creek, the still water in the Toronto labs, and the ARUMators was oxygen, which was preventing the proliferation of the anaerobic bacteria that reduce sulphates.

All during this period, Smith had been conducting experiments in the lab, germinating cattails for parallel projects that were underway at Denison and at a mine in Newfoundland. The work at Levack demonstrated that cattails don't like being dug up and transplanted, so Smith was trying to find the best way to grow them from seed. Did they want to be seeded on wet ground just above the waterline or flooded ground just below it? Or some combination of the two? The seeds that did best, he discovered, were planted on floating peat mats with a constant level of moisture. At about the same time, he came across a report by researchers looking for a way to kill cattails in swamps that complained about their tendency to form floating mats. The combined mass of their roots was so dense that they trapped gasses released from the sediment below, which kept them afloat.

Inco ARUM system

No one recalls now who thought of it first but the answer to the oxygen problem at Makela was clear; cover the cells in floating cattails. Smith built rafts made of nylon mesh strung over a ring of watertight plastic pipes, and seeded the cattails in a bed of peat. They germinated quickly and their roots soon trailed in the water. While not impeding the flow of water they were entangled tightly enough to create an environment for colonies of bacteria, thriving on the polysaccharides they extruded. When the roots died, they would fall to the bottom, where the hay and flax had been dispersed, adding to the reserves of carbon in the sediment. In effect, the system created upper and lower layers of sediment, both providing habitats for sulphate reducing bacteria (SRBs). By the end of the 1992 the pH of water emerging from the cells had increased from 3.2 to 6.45 while its burden of dissolved nickel had dropped from 36.3 to 0.17 milligrams per litre.

New Challenges

Throughout this period, Boojum had other irons in the fire. In 1984 Smith had gone back to university, and under the direction of Professor Sawa had written a master's thesis on the growth requirements of Chara. Researchers had always assumed that Chara like other algae derives its nutritional needs from the water around it. Smith, noting the mass of rootlets on the Chara he was growing in aquaria, couldn't believe they were there only to anchor the plant. He demonstrated, with his thesis that, in fact, they drew phosphorus from the sediment. He described some of his findings at his first public presentation, at the annual meeting of BIOMINET in Mississauga in the fall of 1985.

The talk was slightly complicated by the fact that his slides were in reverse order forcing him to give his talk back to front. He described the work that had been done at Denison, where after the first disastrous transplant attempts Chara had taken hold in the tailings pond and was accumulating calcium, magnesium, aluminium, uranium and, in particular, radium from the water to a level 44,000 times as high as background. In conclusion, he said, large colonies of Chara could eliminate the need for on site treatment plants.

That evening, at the conference banquet, Kalin and Smith split up on the theory that this would expose them to more contacts. Smith ended up at a table with a cluster of senior mining executives who perhaps inevitably, began to rib him about his idea that he could solve a major industrial problem with seaweed. But he held his ground. If you want to get contaminants out of a water stream, he said, it was hard to imagine anything doing better. One of the engineers at the table, a couple seats down from Smith, had sat quietly through the exchange. As the desserts arrived he leaned forward and began to speak quietly.

"We've got a mine up north…", he said.

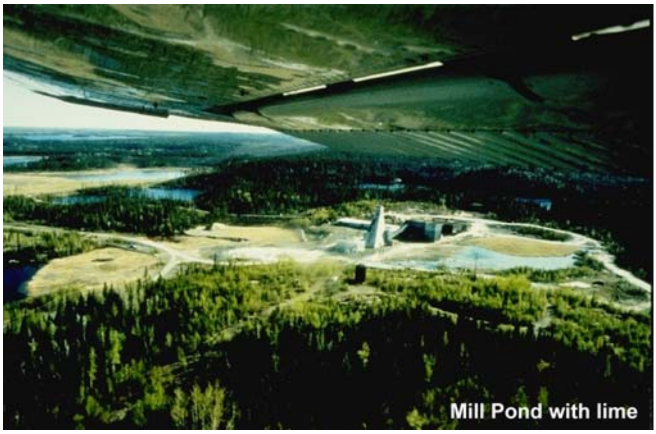
The engineer was Godfrey Macdonald, a senior executive with BP Selco and the mine in question was at South Bay, located about 400 kilometres northwest of Thunder Bay, Ontario. It had generated copper, zinc and some silver for ten years, until it was closed in 1981 leaving behind about 750,000 tonnes of pyrite tailings. The company had partially backfilled the mine but the Ontario Ministry of the Environment wanted the site restored to its natural condition meaning that the buildings would have to be cleared and the tailings re-vegetated. The company had tried, with mixed success, to grow grass on them.

South Bay overview

The mine was almost completely surrounded by a ring of northern lakes, the largest of which was Confederation Lake, well known to fishermen for its trout, pike and walleye and a special concern to the MOE. The property drained to the northeast, into the ring of smaller lakes, but it hardly mattered because, one way or another all of them flowed back to Confederation. The conventional approach, recommended by a consultant, was to install a treatment plant but the site would be generating acid for 100 to 35,000 years which seemed like a long time to be treating wastes. Smith told MacDonald that he should talk to Kalin. A few weeks later, she flew to the site.

Glenn Mallory, the mine supervisor took Kalin on a tour of the site. The immediately pressing problem, he said, was Mill Pond, which received run-off from the area of the mill, and which was heavily contaminated with copper, iron, lead, and zinc. The company had regularly dosed it with limestone, which had created a contaminated alkaline sludge on the bottom. If she could clean up the mess, he promised her, there might be more work for her.

The Levack experiments were underway by this time and Pre-bog Acid Creek had demonstrated the effectiveness of ARUM. So Kalin told summer students working at the site to shovel two truckloads of sawdust and hay bales into the pond to stimulate the growth of bacteria. The pond quickly turned green. Algal physiologist Bill Wheeler, who had joined Boojum that summer, confirmed that that the algae were taking up metals. Macdonald invited Kalin to decommission the entire site, to take down the buildings, get rid of the building materials and equipment, vegetate the tailings, and treat the run-off.


Mill Pond with lime

Robert van Everdingen, a geochemist working with Kalin deter-mined that most of the run-off was finding its way into Boomerang Lake, which had been acidified. This could not be prevented since the tailings were leaking into the fractured bedrock, and reaching the lake with the ground water. But it was possible, Everdingen concluded, to divert all the flow from the site into the lake with drainage ditches. Kalin put forward a proposal at a meeting with MOE officials that made a virtue out of necessity. If the MOE would let her route all the contaminants from the site into Boomerang, she would guarantee that they never came out. The Ministry agreed.

Because of the deep sediment on the lake bottom Boomerang was already an effective biological polishing pond. Kalin made it better with the introduction of aquatic mosses. These would grow on the sediments slowing the influx of oxygen and creating a better environment for SRBs. She also scattered phosphate into the lake, to function both as a fertilizer for the algae, which would bloom, die and settle to the bottom to provide organic matter for the SRBs and as an agent that would chemically bind iron arising from microbial activity in the sediment that would have otherwise made the water in the lake more acidic. Wheeler's studies of algae trapped in mesh traps confirmed the plan worked.

The lake drained through a long, shallow channel that was almost completely clogged with weeds, a natural filtering mechanism. Kalin scatted 140 truckloads of brush cuttings into the lake to provide structural support for algae. So the entire lake became a cleansing engine driven by ARUM and biological polishing.

* * *

In 1988 Kalin took a call from Michael Babcock, vice president of operations at Eldorado Nuclear Limited, a crown corporation which was about to merge with the Saskatchewan Mining Development Corporation, and to be privatized as Cameco Corporation. The company had a puzzling problem at its Rabbit Lake site mine site in Northern Saskatchewan. Radium was escaping from the waste rock piles and mine slimes and was getting into a string of small lakes. The AECB wanted the company to build a barium-sulphate treatment plant to remove it. But something odd was happening when it got into Lower Link Lake, the second lake in the chain. A lot of it was simply disappearing; at least it wasn't evident in the outflow and no one could explain why. Since regulators hate uncertainty above all else, Babcock needed to find out.

"It's obvious," Kalin replied, "Your lake is filled with some kind of stonewort".

Moreover, she told him, if the Chara in the lake was abundant and prolific the company would never need a treatment plant. Babcock replied that in that case Kalin had better attend an upcoming meeting with the regulators and with the company's consultants who had already designed the plant. Kalin hedged. If she was going to attend such a meeting, she said, she needed to confirm her theory. No problem. Eldorado would fly her to the mine site, she could check for Chara and then fly to the meeting.

The Rabbit Lake mill and mine was one of the largest uranium complexes in the world and is located 500 kilometres north of Saskatoon. Kalin stepped off the plane, into the teeth of an Arctic wind, and a chill factor of 40 degrees below zero Centigrade. She was met by Robbie Scott an environmental technician at the site, in an all-terrain vehicle, with a closed canopy and treads for the short drive down to Link Lake. They parked on the shore, walked onto the frozen lake, and drilled through the ice with an auger that plunged into the freezing water below. When Scott dragged it back, the bit was draped with Chara. Excited, Kalin dropped to her knees and plunged her arm into the water, and triumphantly pulled out a clutch of Chara, which she dropped into a jar of water. She could only say later that it seemed like a good idea at the time. The neoprene sleeve that covered her winter coat began to instantly freeze; the sleeve beneath it was soaking.

"Don't worry Margarete," Scott said. He took her to the ATV and from beneath the seat pulled a quart of pure alcohol, poured it over the arm, and then lit it. Flames briefly engulfed her arm. When they died he peeled off the glove.

"Frightened?" he asked.

"No," she replied.

The quart of alcohol on standby in the ATV was a northern remedy for the cold. Robbie poured the remainder of the bottle over the engine block and ignited it. It burned briefly while Kalin turned the key; the engine moaned but did not start. Grimly they began to trek through the deep snow back to the mill, Kalin with the ice-cold bottle of Chara beneath her coat. The next morning in Saskatoon, at Eldorado's offices she put it triumphantly on the boardroom table.

"There's my weed," she said. The ordeal in the bush soon began to seem mild by comparison to the experience in the boardroom. Neither the consultants nor the regulators particularly wanted to admit that an aquatic weed could take the place of a million dollar treatment plant. What proof did she have? What guarantees would she post? Kalin had come to the meeting with Duncan Moffat, a senior Eldorado executive, and left with him at lunchtime. In the elevator, she said she'd had enough, that she couldn't give him guarantees so there was no point in going back to the meeting. Moffat took her to Babcock's office.

"I'll make you a deal, Swamp Doctor, " said Babcock. "You go back in there and I'll go with you."

Back in the boardroom, Babcock said "what's the problem? This woman says that Chara will take up the radium and we're going to try it."

And that, Kalin says, was that. The following summer Kalin and Smith supervised the relocation of tonnes of Chara into the Upper Link Lake, the first lake in the chain, to recapture the radium as soon as it began to move into the environment.

*   *   *

Word spread and with it came new contracts. For ASARCO Kalin designed and supervised the construction of a biological polishing pond to remove zinc from the outflow at Buchans Mine in Newfoundland. The Cape Breton Development Corporation commissioned her to design an ARUM system to treat the seepage from a coal pile at Victoria Junction and an abandoned coal dump at Selminco.

BP Selco was pleased with the results at South Bay and sent Kalin to its state-of-the-art copper-zinc mine at Selbaie in Northern Quebec. BP Selco shared the holding with TCPL Resources and with Esso Minerals.

But just before she got on the site, Billiton Metals Canada Incorporated, a subsidiary of Royal Dutch Shell had bought out the Esso shares.

But all that was at a corporate, economic level that was of no concern of Kalin. She was more interested in the algae growing in the drainage ditch and in the fact that for the first time, she had a chance to influence the management of wastes that were still being generated. There was a lot of iron in the Selbaie waste rock and acidities were so high that a consultant had estimated that it would take up to $65 million, 5.7 million tonnes of lime, and 285 years to neutralize and remove the metals from the run-off.

That summer Kalin, and hydrologist Albert Vonhof with a large Boojum crew took samples of the biota and the run-off from the site, and measured the flows. Two years later, in 1991, Selbaie engineers built a demonstration decommissioning system to Boojum specifications. Run-off from the waste rock was gathered in a large tank, and then released in a controlled flow into a series of cells where it reacted with phosphates, cattails and algae before being released into an old pit that would be flooded to provide the final measure of biological polishing. The system was up and running in 1993, and the data began to flow back to Toronto. It consistently showed unexpectedly high levels of iron, which remained a mystery until Smith flew into the site and noted that the Selbaie engineers, as an economy measure, had used a salvaged iron tank to feed water into the system. The tank, of course, was dissolving in the acid. It was an easy fix and the system began to work.

Kalin and Smith began to pursue other new ideas at Selbaie. Why not incorporate phosphate and seeds into the tailings slurry, as it left the mill? The phosphate would bind to the iron in the waste slowing down the generation of AMD, and it would also stimulate the growth of sulphate-reducing and iron-reducing bacteria. Instead of simply treating AMD, it might be possible to prevent it. Kalin wrote a comprehensive proposal to decommission the site, but this went nowhere. As far as she knew, the major beneficiaries of the work done there were the migrating geese that flocked to the tailings pond, which was covered with cattails. But although she didn't know it, word of her innovations was working its way up the corporate ziggurat to a level where real decisions are made.


Selbaie active tailings work


Phosphate / manure Stanrock plots

Rise and Fall

Early in September 1990 Kalin and Smith were part of a trade mission to Amsterdam, sponsored by Industry Canada. While they were there a Canadian trade commissioner told them that senior executives at a company called Billiton International Metals B.V. based in The Hague wanted to meet with Kalin. It did not occur to Kalin, until years later, to wonder how the executives of a mining company in Belgium had heard about her work. In fact, they had seen reports of her work at Selbaie, where Billiton held a 38 per cent interest. Kalin made travel arrangements while Smith drew up a series of overheads with a magic marker to help her explain the principles behind Ecological Engineering.

The street address that she had been given turned out to be a soaring office tower, the head offices of the Royal Dutch Petroleum Company, and principle shareholder of Shell Petroleum. She told a security guard she must have come to the wrong building but he sent her to the fifth floor, to Billiton's corporate offices. It was a subsidiary of Royal Dutch/Shell and one of the largest mining companies in the world. A receptionist led her to a boardroom where six men in good suits smoking good cigars were waiting. The receptionist gave her coffee in a gold rim cup.

Someone invited her to describe her work so she began to sell Ecological Engineering. She handed out a list of her publications and the Boojum brochure and went into the pitch she had been making for days at the trade show. She talked about ARUM, and Chara and biological polishing, showed Smith's overheads and described the inadequacies of conventional technologies. After 15 minutes she ran out of things to say. Someone asked her what she knew about eucalyptus trees; as it happened she knew they grew well on tailings sites, but that their large tap roots were a conduit for oxygen and water so they were more of a problem than a cure.

She said that if they had asked about tailings in a temperate climatic zone she could give them a better answer. She had been to almost 100 mine sites, she explained, and at all of them had measured the pH, the redox, and the conductivity and at most had taken samples, all of which had been analyzed, digitized, organized and categorized at a cost of up to a thousand dollars a sample, usually paid by the project sponsor but sometimes by Kalin. The upshot of all this was a database, indexed and cross-referenced that was potentially worth millions. Everyone seemed impressed.

"Miss Kalin, are you available?" someone asked.

"That depends," Kalin replied cautiously. She was busy but she thought she might be able to spare a day or two a month on a new contract.

"And then they said, 'thank you', we'll get back to you."

Kalin had only been back in Toronto a couple of days when she took a call from an accountant with Billiton Metals Canada Incorporated (BMCI) who wanted to see her books. This seemed strange but she assumed that big corporations need to know that their sub-contractors are solvent and reliable. Moreover, she was proud of her books and felt she had nothing to hide. Boojum had grown steadily and now employed nine gifted scientists either full time or on contract. It had contracts with INCO, ASARCO, DEVCO, CAMECO and BP Resources and in the last fiscal year had earned $665,000 of which $131,000 was profit. But the Billiton accountant didn't seem overly impressed; Kalin helpfully suggested that perhaps the type was too small making the numbers hard to read. No, he said, they were fine.

In October, Andrew Flett, president of BMCI called with an offer. Billiton wanted to buy all of Boojum's technologies and processes and more particularly, its database for $1 million (U.S.). The company would still belong to Kalin, but she would phase out her current contracts by the end of 1991, and for the next four years devote herself exclusively toward Billiton projects; for this she would receive a further $1,169,500 (U.S.) a year.

But naturally, there would be a catch. First, Kalin would have to present herself to the Shell's research facilities at Sittingbourne, in the United Kingdom, to explain Ecological Engineering. Moreover, Boojum itself would have to put on a brighter face since it would soon be receiving Billiton mine managers from all over the world; they would describe their problems and get a crash course in Ecological Engineering. So the company's current, dingy offices at Dundas Square were out of the question; Boojum would be taking on new staff, up to 50 or 60 people, so it would need more and better space. And the old clients would have to go as well; as soon as their existing contracts were complete. Boojum would devote itself exclusively to Billiton. To negotiate all this, Billiton would provide $50,000 for legal expenses.

In December, a few days before Christmas, Kalin flew to England to meet with the scientists at Shell's research facility at Sittingbourne. She arrived at 6 a.m. and was taken by chauffeur to Sittingbourne. Several scientists were waiting for her; one gave her machine coffee in a paper cup and invited her to explain Ecological Engineering. Someone told her bluntly that she was there to prove her competence. Kalin replied that if the atmosphere was going to be antagonistic there was no point in proceeding. After that things settled down. She must have passed the appraisal because negotiations continued.

On May 1, 1991, with help of a $35,000 Billiton loan Boojum moved into an elegant, 6700-square-foot office on the upper floor of a handsome, refurbished brewery at 468 Queen Street East. The monthly rent on the new space was almost $8,000 while taxes, maintenance, fees, parking and utilities pushed it close to $24,000 but, of course, money was no longer an object. The ceilings were high, the green tiled floors gleamed and the southern wall consisted almost entirely of


468 Queen St. East 4th Floor

sliding glass doors, overlooking a balcony that was perfect for growing trial plants. The space included a workshop to build experimental equipment, sedimentation traps, cattail floats and assorted frames and cages and a laboratory, equipped with eight new sinks, drying ovens, ventilators, and benches. All that was needed, in the new lab, to solve the problem of mine wastes was the human ingenuity that would be provided by the new staff.

The lawyers, however, were still hammering out the details of the new agreement. Kalin had flatly refused to give up her old clients, but that didn't seem to be a deal breaker. And there was some confusion over whether or not the federal government, which had financed much of her research, had any claim on the technologies that it generated. But that got sorted out. Conceivably, Billiton's lawyers found out – as Kalin had found out years earlier – that you can't get a patent on Mother Nature. In the final analysis her technology consisted of nothing more complicated than helping ecological systems heal themselves. According to Flett, Billiton's lawyers had concluded that the costs of protecting the technologies, most of which were still in Kalin's head, would exceed the cost of buying them from her. For whatever reason, Billiton suddenly lost interest in owning the Boojum processes.

But Flett didn't want to give up on the idea of a joint venture and neither did Kalin. So they made a new deal. Sittingbourne would still get a chance to review Boojum's ongoing research and discoveries and its database, Kalin would still meet with and educate Billiton's operations staff and she would oversee the remediation of their sites at a price to be negotiated for each job. For this she would get $155,000 (U.S) immediately and $350,000 (U.S.) a year thereafter. Kalin liked the new deal. It gave her less money but more autonomy.

In September, 1991 Kalin and two of her scientists, Bill Wheeler and Jim Cairns, met with Chris John, a scientist from the Sittingbourne Research Centre and took him on a tour of the sites in Elliot Lake and to Levack and Makela. John was struck, like many visitors before him, by the enormity of the tailings in Northern Ontario. "This is crazy", he said to Kalin, on the drive back to Toronto. "We're doing all this work to clean up the water after it leaves the tailings. We need to find something that stops acid generation in the first place."

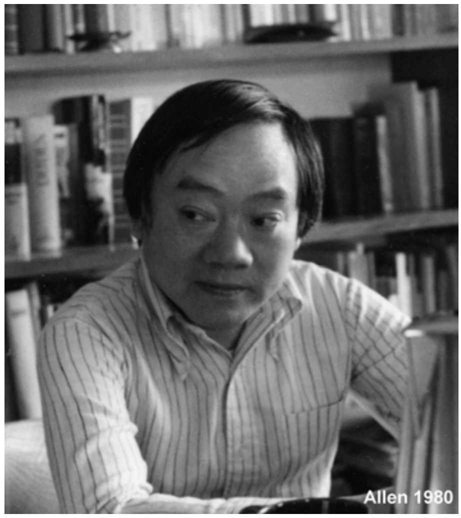
Kalin replied that the only thing she knew that directly inhibited the oxidization of iron was phosphate. But it occurred to her, driving south,

Phosphate rock drum experiment

that John had made a good point. Back in Toronto, she arranged for the delivery of three tonnes of pyritic waste rock from Selbaie. It arrived by truck, packed in drums, which were too heavy to be moved on a trolley; so Boojum's new staff marshalled themselves in the parking lot and hauled the rocks upstairs in buckets. They were loaded into 15 plastic garbage cans, which were strategically dispersed – according the directions of a structural engineer – along the length of the south-facing balcony as part of an experiment designed by Dr. Grant Ferris, an associate professor specializing in biogeochemistry and biomineralisation at the University of Toronto. In each barrel Ferris distributed precise amounts of phosphate and waited for the rainwater that would trickle out the bottom of the barrels. The experiment was still ongoing when catastrophes began to strike.

Allen Yen had last worked under the banner of Boojum Research in 1984 when he finished a prototype for a geographic positioning system. Since then, he had been Boojum's godfather, often visiting the office where he was invariably curious about the tasks and technical problems of every employee. Because of his expertise with computers, Boojum always had the best hardware and software on the market. Moreover, he was an unwavering source of support and feedback for Kalin. On May 28, 1993, Yen suffered a massive stroke and died two days later, holding Kalin's hand. Kalin turned to the attending nurse and said, "He's dead. Now what do we do?"

In July, Flett called to say that Shell had sold Billeton Operations, and with it, had lost all interest in mine-related environmental problems.



So Boojum was now on it's own. Drastically overextended and counting on Billiton contracts, which had never arrived, the company was on the ropes. Within a few months, $70,000 shy on the rent at Queen Street, Kalin gave the landlord a promissory note for half the amount and agreed to move into two rooms on the fourth floor. The downsizing began in earnest. The three tonnes of waste rock on the balcony were unpacked and transferred first into storage and then to Kalin's back yard where the experiment continued. The lab was dismantled and $45,000 worth of laboratory equipment began to bounce around the country, landing first in British Columbia, where they helped an entrepreneur grow seaweed then to a barn belonging to Martin Smith's father. It was finally donated to the Ryerson Polytechnic Institute, and is still there, part of the Margarete Kalin Laboratory. Smith and Kalin hauled the desks, chairs, drafting tables, bookshelves, and waste paper baskets from the offices down to the street. Kalin pushed a trolley loaded with desk drawers onto the street just in time to see a taxi driver trying to cram a desk into the back of his cab.

"Come back up with me, and I'll get you a screwdriver, " she offered.

She told him the whole story going up on the elevator and coming down with more furniture. When he had the desk apart and in the cab he turned and gave her $5.

"You need this more than I do lady."

But while it was one thing to get rid of furniture, it was another to dispose of people. Boojum by this time had a staff of 16, including scientists, technicians, and a secretary. Smith and microbial consultant Andrew Fyson went to Beak Consultants taking some of their equipment and their projects with them, but were still available to Boojum on a contract basis. Wieslaw Poliszot, a programmer who had been building the database found a new job at Geomar Geophysics Ltd., and algal-physiologist Bill Wheeler went to work growing seaweed for the consumer market. In a few months, only Kalin remained working amidst cardboard boxes. But she still had her database, her ideas, her old contacts, and her determination. She began to dial for dollars and gradually new work began to trickle in.

Kalin had refused, in all her negotiations with Billiton, to give up her old clients. Now they saved the company. Cameco was closing out its B-Zone pit and wanted Kalin to assess it before and after it was flooded to document the biotic processes that would take place there. ASARCO began to route effluents from other mineshafts at Buchans into the polishing pond, and needed an analysis of the results. ASARCO had also developed passive treatment systems at a subsidiary mine in Salt Lake City, and wanted those evaluated as well. The World Bank hired her to evaluate the effects of modern mining methods in Upper Volta, now Burkino Faso, in Africa. And Anglo American Gold hired her to design a passive treatment system for a mine in Brazil. As the contracts came in the staff began to trickle back.

And then Alex Jakubick called. He said he'd heard Kalin speak at Vancouver and wondered if she'd like to attend a workshop in Germany.


Brazil ARUM system

Germany Again

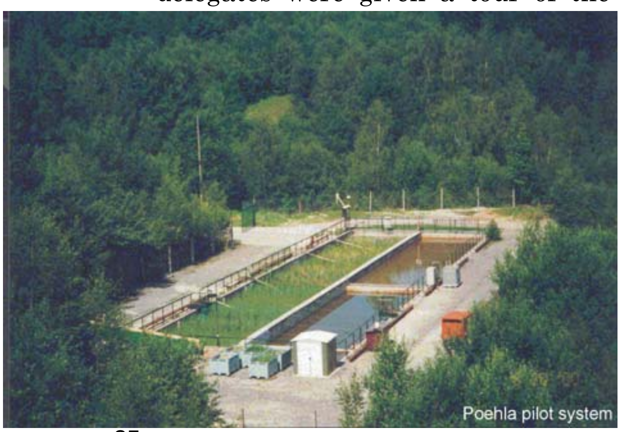
Somewhere near Dresden, in Saxony, Kalin took a turn off the autobahn and lost her way ending up, in the dark, in what seemed to be a field of potatoes. She must have been in a valley because the cell phone didn't work but finally she got through to Jakubick, who guided her into Chemnitz where she arrived at midnight. Wearily she fell asleep.

At breakfast the next morning, Kalin sat by herself at a cafeteria in the Wismut conference centre, listening to the blur of English and German voices around her. It struck her that the conference had brought together two engineering cultures with completely different styles. She listened absent-mindedly to North American engineers complaining about the obsessive exactitude of Germans and their love of regulation and detail. And to Germans complaining about the slapdash, get-it-done style of the Americans and Canadians. She had loyalties, she realized, to both camps.

Kalin presented a paper 'The Use of Natural Phosphate Rock to Reduce Acid Drainage from Pyritic Waste Rock' which described the phosphate experiment which had begun on the balcony at Queen Street, and that ended, after the crash, in her back yard. For 989 days she had faithfully monitored the rain and melt water that trickled through 13 barrels of waste rock, four of them controls, and nine primed with phosphates, saving the samples until they were analyzed with funds from the National Research Council of Canada. The run-off from the control barrels had a pH of 4.2 and carried substantial slugs of iron, zinc and copper. In some barrels the phosphate had been sprinkled on the uppermost rocks, as a mining company might scatter it on an existing waste rock dump; in these the pH of the run-off was 5.8 with a corresponding reduction in dissolved metals. In other barrels the phosphate was mixed throughout, as could be done at an existing mine if the phosphate was added incrementally to the waste stream; from these the run-off was neutral and the dissolved metals almost non-existent.

Kalin was proud of the experiment. More than treating run-off it suggested the possibility that acid mine drainage could be prevented. And it reflected her current passion and the state of her search for the Snark that might be a Boojum. It was well and politely received at the conference, but the run-off from the Poehla mine was not acidic. So acid reduction was not an immediate goal of the Wismut team. She was invited to speak at a panel discussion where, as always, she complained about the reluctance of engineers to heed biologists.

At the close of the conference delegates were given a tour of the



Poehla pilot system

Poehla pilot system. It was situated at the top of a long narrow valley typical of the Erzgebirge's Mountains. The system covered 415 square meters, divided into five cells: a settling chamber in which the iron was allowed to precipitate out of the water taking some of the arsenic and radium with it and filtration chambers in which the water flowed through gravel filters, which would be fertilized to promote the growth of micro-organisms. Officially the system was not yet in operation, although it had already been flooded. Once in operation it would be expected to remove contaminants, mostly arsenic and radium from 3.5 cubic metres of water an hour. Like the cells at Makela, it diverted the flow from a run-off ditch feeding a treatment plant. If a full-scale version of the pilot could be made to handle 17 cubic metres/hour the plant would be shut down.

Kalin thought it was a beautiful system although typical of the work of engineers with its emphasis on right angles. But the most extraordinary thing was its provision for gathering data. No less than six monitoring stations were built into the system, taking the pulse of the water – the acidity, the redox, the electro-conductivity, radium, arsenic, calcium and phosphates – as it flowed from chamber to chamber. And no one seemed to be worried about the cost of analyzing all this. It was data-gathering on a scale that she had always dreamed of doing, data that showed not simply whether a system worked, but where it succeeded and where it failed, and ultimately why. On the last night of the conference, with senior Wismut executives, she declared unequivocally that she wanted to get involved in the project.

"Drop by," they said, "Next time you're in the neighbourhood." The invitation reminded Kalin of the invitation extended by Tom Peters almost 20 years earlier, to drop by and see him in Sudbury.

She did drop by again twice in the next three years and watched the pilot system run through its paces. It performed well in 1999 but by 2000 wasn't meeting regulatory standards for arsenic and lead. The problem with the system, Kalin suggested, was that it relied too much on plants, and too little on algae and bacteria. In June 2001, a fax arrived from Chemnitz, offering her a contract to analyze the performance of the pilot system and to help design the full-scale system.

The next time Kalin was in Germany Gunter Kiessig, a Wismut director, told her that he felt as though the whole world was watching the Poehla experiment and added, "Wir sind zum Erfolg verurteilt"; we are sentenced to succeed. Failure, in other words,

was not an option. Which was fine with Kalin since the entire point of the Peohla experiment was to eliminate a treatment plant. The run-off from the Poehla mine and the waste rock pile might only be 17 cubic meters an hour, a trickle compared to the deluge of contaminated waters pouring from mine sites all over the world. But if she eliminated the need for one treatment plant, others would follow.

Acknowledgment

The complexity of acknowledging the contributions made by so many people over so many years in daunting. I thank Kenneth Hare who, as Director of the Institute of Environmental Studies, set the course of my life, by encouraging me to look at the ecology of uranium mill tailings. To this day a photograph of Dr. Hare overlooks my desk. I thank Ron Barsi, then with Environment Saskatchewan, who understood fast and early in the game what the "Swamp Doc" had in mind. Through him all the abandoned sites in Saskatchewan were added to the portfolio.

Foremost in my mind are those individuals who, in the early years, supported me philosophically, by listening, asking questions, encouraging me and extending to me sage words of warning. Clyde Lendrum from Eldorado, Chuck Charkavatti, Denison Mines and Ron McCready, Canmet were essential to the survival of Boojum in its first couple of years. Like many clients who came later, they recognized the passion of our intent if not always the expertise of our methods.

One may ask what is Ecological Engineering? In part, it is geochemistry, which was provided for years by Robert van Everdingen. It is fathoming the flow of water above and below the ground, which has been done for us by Albert Vanhof, our hydro-geologist. And it is interpreting cause from effect, which has been done by Andrew Fyson, our microbial ecologist and master of "reverse microbiology". There would be no Biological Polishing without algal physiology as provided by Bill Wheeler or without the efforts of Mary Olaveson who over the years tirelessly identified the algae we brought back from the field. Without programming, as provided by Wieso Poliszot, data is merely random noise. And then there is Yan Gan who has added her skill in experimental soil science to our laboratory. All these gifted scientists have been my teachers; they were also a bulwark of support in difficult times.

Since this note is intended to commemorate contributions to Boojum, it is difficult to acknowledge Martin Smith who for 20 years, come hell or high water, has been Boojum. For such support there are no words.

In writing this reflection, I wonder if I have said 'thank you' often enough to each and every member of the team that built Boojum. I hope you can all forgive my failings as a leader. My wish for the future is only that we continue to work together as well and as effectively as we have in the past. We have built a great foundation. To all of those who helped, thank you.

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Grylls, Brian
Grzegorczyk, Iwona
Hopkins, Eric
Kam, Angela P.A.
Keith, Christopher
Olaveson, Kelly M.
Poliszot, Anna
Raskauskas, Judita
Remtulla, Alim
Simmons, Denina B.D.
Smith, Monica K.
Sun, Paul
Stamatiou, Evangelos E.S.
Talukder, Farhan F.
Thomas, Nikhil

Trainees and Volunteers

Hansman, Eric
Karunathirajah, Nelson
Shantry, Michael G.
Tortorelli, Joseph
Wanger, Gregory

Postscript

Take a chance on me
Gonna do my very best and it ain't no lie
If you put me to the test, if you let me try

Take a chance on me
(That's all I ask of you honey)
Take a chance on me

The disc jockey at Boojum's 20th anniversary party, on a rainy day in the summer of 2002, was under standing orders to keep Kalin's favorite Abba tune high on his playlist. 'Take a Chance On Me' could have been the theme song both of her career and Boojum's 20 years in business. The gathering of 120 old friends at the Black Creek Pioneer Village in Toronto brought together many of the personalities that had played key roles in Boojum's evolution. Astronomer Wayne Cannon paid tribute to Allen Yen, Boojum's founder and guiding spirit, and his role as a pioneer of Canadian – and world – radio-astronomy; Bob Michelutti, from Faconbridge and Brian Bell from INCO were reminders of Boojum's early years in Sudbury. Also at the party were Mary M. Olaveson, an algal taxonomist who had identified phytoplankton samples collected by Kalin from mine dumps all over Canada, and Brenda Stanek, head of the inorganic analytic lab at the Saskatchewan Research Council, who had done the same for mineral samples. Martin Smith, who had been with Boojum from the start, recalled the chaotic early days when the tiny company took on projects that no other firm would touch.

"Margarete would get off the phone and say 'we're going to do 'this' for a particular client'," he said. "And I would have an instant anxiety attack."

"'We can't. We don't know how. Why would you promise such a thing?"

"But then in the next day, or the next week, ideas would start coming out and the project would start to get interesting. And that was why people came to us; they always came with an impossible task."

The anniversary party seemed to reflect Boojum at the height of its prestige and success. The company had pulled itself together after the Billiton fiasco, Chara was blooming in the Link Lakes sequestering radium in lake sediments, unacceptably high nickel levels in a flooded pit mine in Saskatchewan were rectified when Kalin and Smith found nickel in nearby road fill, polishing ponds were cleaning effluents from the Buchans Mine in Newfoundland, and most intriguing of all, rainwater percolating through drums filled with waste rock and a sprinkling of phosphate wastes, a long term experiment that Kalin had funded on her own, emerged clean at the bottom. The exact how-and-why of this was a tantalizing question that was fully engaging Kalin and her co-workers.

Boojum's greatest achievements were at the South Bay Waste Management Area in Northern Ontario, a former mine site that had become, in effect, a showpiece of alternative technologies. An array of projects underway on the site had a dual purpose. They not only contained contaminants on the site, but they had generated vast amounts of raw data that could be applied elsewhere. Cattails, set afloat on rafts on a tailings pond, sheltered it from the wind, reducing agitation and oxidation, and provided, in their roots, a secondary habitat for sulphur reducing bacteria; the precipitation of iron on a beach of the pond, with a consequent drop in pH, was countered by the addition of 10 truckloads of rotting bark – wood waste left in the forest after the logging – which stimulated the ARUM process and almost immediately elevated the pH; the site of the former mill on the site was generating acidity and dissolved zinc until it was covered in 2000 pounds of wood ash from the nearby saw mill, which soon supported a lush carpet of moss; 18,000 brush cuttings had been dropped into Boomerang Lake and within two years each cutting supported 20 kilograms by dry weight of algae which in turn consisted of 4.24 per cent iron, 0.02 per cent copper, 0 .003 per cent lead and about 0.05 per cent zinc all sequestered from the water.

The discovery that a plume of ground water was moving beneath the tailings and transporting contaminants to nearby Mud Lake inspired a plan that was conceived in equal parts desperation and genius. Analysis confirmed the presence in the plume of diverse bacteria some of which potentially could re-mineralize the dissolved metals in the plum… but there was no room between the tailings and the lake to set up treatment ponds where the bacteria could thrive. Instead, urea and sugars were fed into the plume; the bacteria proliferated, and the flow of contaminants reaching Mud Lake dropped substantially. In another promising experiment phosphate and manure were ploughed into the surface of the tailings deposits at both South Bay and an INCO tailings at the Dennison Mine and ASARCO tailings at Buchans, the manure to nourish heterotrophic, acid-reducing bacteria, and the phosphate to precipitate iron which formed a shallow layer of hardpan effectively sealing the tailings from rainwater.

So there was much to celebrate at Boojum anniversary. And yet…

Nothing is ever certain at a remote northern site. Muskrats moved into the tailings pond, which was good news because it was an indicator that the water quality was improving; the bad news was that they were hungry and ate the roots of the floating cattails, killing them. More seriously, in the fall of 1999 a family of beavers built a dam across the outflow of Mud Lake, at the narrows leading into Amanda Lake, both small lakes on the border of the site. As beavers are a protected species, the dam could not be breached without permission from the Ministry of Natural Resources. By the spring, as the Ministry continued its deliberations, the water level of Mud Lake had increased by a half metre flooding parts of the tailings and mobilizing contaminants. Finally, the Ministry authorized the destruction of a portion of the damn. But by this time the flooding had raised the contaminant levels in Mud Lake, and the breach released a pulse of 30 tonnes of acidity into Amanda. For years Amanda's natural buffering capacity, and the ongoing addition of phosphate in Mud Lake, had stabilized its pH near neutral. But this was depleted by the pulse and by December, the pH of the lake was hitting 3.9.

To Kalin the solution was obvious. Just as she had applied wood ash on the Mill Site, she intended to scatter it in the winter on the ice cover of Amanda Lake so that it would fall to the sediments with the spring melt. Wood ash contains potassium oxide which reacts immediately with acidity and calcium oxide which reacts more slowly. So it provides both an immediate and a long term antidote to acidity. As well, the calcium, potassium and a small component of magnesium make it an effective fertilizer. A pilot study, with Mud Lake sediments had shown great promise and Kalin had ordered 70 tonnes of ash, previously parked at the municipal dump in the small town of Ear Falls, and had stored it on-site under tarpaulins. It was a classic solution, an elegant application of the principles of ecological engineering; solve problems associated with the wastes of one industry with the wastes of another. Restore balance. But this too required permission from the Ministry of Natural Resources and Northern Development (MNDM). To the regulators, the plan sounded too much like dumping more pollution into an already polluted lake system and it was turned it down.

But notably absent from the gathering was Dave Porter, the corporate executive who administered and sponsored Kalin's work at South Bay. Porter's company had inherited South Bay, as residue in a larger corporate transaction and in 1990 had turned it over to the provincial government; the fact that the government had accepted the site, was a measure of Kalin's early achievements there. The work wasn't finished, however, and the company's continued support for Kalin and her projects, was entirely voluntary. Porter missed the party because he was at a meeting in Kenora, Ontario with bureaucrats from the Ministry of the Environment (MoE) and the MNDM to discuss final measures that would finish the work and allow the company to leave gracefully. The regulators had not allowed wood ash to be dispersed in Mud Lake; would they at least allow it to be dropped upstream into Mud Lake? No.

For Porter this was the last straw. As he later told Kalin, if the regulators couldn't grasp the underlying logic of wood ash applications they would never understand any of her work. In the summer of 2003, the company withdrew its support leaving Kalin to deal directly with the government.

Kalin's work had always defied classification. Her treatment scenarios were based on an intimate understanding of a given site and careful manipulation of the plants and bacteria that were already there. Conventional treatment plants delivered a partial solution to acid mine drainage that was brutally expensive but they provided a quick fix, at a predictable cost, over a predictable time frame, all virtues in the eyes of mine managers and the engineering fraternity in and out of government. Baffled by the complexity of Kalin's alphabet soup of treatment scenarios strategies - PHITO, ARUM, PET, PHITO – the MNDM invited bids from mining consultants to evaluate the status of the site, the success of the projects already in place there and to recommend treatment scenarios "giving preference to passive methods/technology to the extent feasible". There was an inherent conflict of interest in the call for proposals in that it invited Kalin's mainstream competitors to decide the fate of treatment scenarios which by their nature challenged the status quo. But no one seemed to notice.

Kalin was kept in the loop to the degree that the ministry unofficially sought her opinion on the firms that bid on the job. She endorsed a proposal from Golder Consultants, having met some of the firm's senior executives at various conferences and seminars and in the belief that they understood and endorsed the objectives of her work. In due course, Golder won the ministry contract. Kalin enthusiastically spent hours on the phone talking with Golder's researchers and sent the firm copies of the 21 reports that she had written about South Bay. It struck her as odd that no-one at Golder intended to actually visit the site.

Golder's report, delivered to the MNDR in March 2004 was bluntly hostile to any scenario related to ecological engineering. It grudgingly acknowledged that Kalin's technologies had achieved some 'localized' success, but noted high level of contaminants in Boomerang Lake, disregarding the fact that lake was being purposefully used as a contaminant sink. And it noted darkly that Amanda had recently been hit with a pulse of acidity that had never been corrected. Nowhere in the report is there any acknowledgement that there had been a substantial reduction in contaminants leaving the site or that all of Kalin's projects had been realized on the shoestring budget of $1.7 million over ten years.

All of South Bay's problems, the Golder report confidently concluded, could be solved by the construction of a conventional treatment plant, and its necessary auxiliaries, a grid of drainage ditches to feed the plant with run-off, a containment facility on the existing tailings to hold the lime sludge from its operations and a 750-km power line to deliver electricity. All of this, it calculated for an initial expenditure of $3 million and a 50-year operating budget of $25 million. And… oh yes… the plant would have to be operated in perpetuity.

The MNDR quietly shelved the report but it still didn't know what to do about South Bay. Kalin offered to continue her work there, raising the finances herself from research organizations and the industry. The ministry tentatively agreed to this… provided that she indemnified it for any potential damages associated with her work. In the view of Boojum's lawyer this meant that the next broken beaver dam could potentially cost the company millions. Kalin declined. The South Bay Mine Site is now just another abandoned mine site like thousands of others in Ontario. Kalin's projects there, for all their early success and potential, languish.

The Golder fiasco was not Kalin's first encounter with the deep vein of hostility that runs through the mining industry – and its regulators - towards passive, ecologically based technologies. Nor was it the last. Her next encounter with it, ironically, grew out of her designation, in 1993 as 'a distinguished lecturer' for the Canadian Institute of Mining, Metallurgy and Petroleum (CIM). The award was given to her "in recognition of professional dedication to developing the concept of ecological engineering, for prevention of acid generation and metal dissolution from mine waste rock and tailings thru innovative applied research." She seized the opportunity, on a national tour, to explain and demystify ecological engineering. Peter Kresin a senior executive with Placer Dome, heard the last of her talks in Ottawa and approached her afterwards to talk to her about waste management issues at the Musselwhite Gold Mine in Northwestern Ontario. Musselwhite, ironically, was not far from South Bay and, like the South Bay site, was situated on a narrow neck of land between northern lakes. But unlike South Bay, the mine and its mill were still in operation. Perhaps, Kresin suggested, it would make sense to implement ecologically engineered strategies *before* the mine closed, anticipating decommissioning problems. Kalin had been waiting 20 years to hear a mining executive say this, and enthusiastically agreed to visit the site.

After the tour on February 3, 1994, she met again with Kresin in Thunder Bay, and gave him her first impressions of the site; much could be done there with ecological engineering, she concluded. Kresin was impressed and subsequently Kresin sent a memo to eight corporate staff members. "I still believe that we have an opportunity to look forward to see what we can do during the operating phase to prevent acid drainage from tailings at closure by considering an ecological engineering approach," he wrote.

Kresin got a reply back the same day from Ross Gallinger, Placer Dome's Vice-President of Sustainability. Gallinger launched his email by clicking Reply All; sending his message to all of the original recipients. He clearly had not read through the entire list. If he had, he would have noticed that last name on it was Margarete Kalin.

"I have some concerns with Boojum's abilities to deliver," Gallinger wrote. "Margarete was funded extensively during the MEND program and never delivered. I polled my industry co-horts to see if there has been something new that she has delivered, and they were at a loss to provide any positive feedback. Apparently, she has been doing 'research' for many years on the McIntyre tailings in Timmins, but has not produced any results, nor has she made any recommendations on how to remediate the acid drainage situation."

His criticisms were grossly unfair. For a start Kalin had never done research at Placer Dome's McIntyre Tailings. She had been there in the late 1980s but only to collect algal samples. True, she was funded by MEND, the Mine Environment Neutral Drainage program of the Canadian government, but the description 'extensive' was debatable; not debatable was the fact that she had always delivered the commodity that was MEND's stock in trade; that is, research reports and new insights into the treatment of acid mine drainage. "Nor has she made any recommendations on how to remediate the acid drainage situation," Gallinger wrote. Kalin had spent her life recommending solutions to AMD, which was why she had won the Noranda Land Reclamation Award for Outstanding Achievement in the Field of Land Reclamation, had been designated CIM Distinguished Lecturer and was soon to win the Tech Cominco Environmental Award. The awards certainly carried more weight than the opinions of Gallinger's unnamed cohorts.

Kalin protested Gallinger's remarks and he duly, albeit grudgingly, apologized. But the Musselwhite Project never got underway and not long after the debacle, Gallinger left the company. The episode was an unfortunate reminder of a mindset that was all too prevalent in the industry.

Like everyone else who was ever celebrated a 55th birthday, Kalin had begun to reflect upon her own mortality and the legacy she would leave behind. In her case, this was more than a metaphysical abstraction; it was a measurable problem in the form of the library that crowded the second floor of her home on Amelia Street in Toronto. According to a rough count it contained more than 1500 titles including 300 monographs, 1000 conference proceedings and reports, and 500 technical reports not to mention dozens of technical and scientific journals acquired by subscriptions that in some cases were unbroken for over 20 years. Erna Cassac, Kalin's neighbour and a retired assistant to the director of the Royal Ontario Museum, had taken on the job of archiving the collection and, where possible, culling it. But it had grown nonetheless and was crowding out the second floor. But what to do with it? The library was the fertile source of many of Kalins ideas. Ron Benn, Kalin's business manager spoke at Boojum's anniversary party and noted that Kalin's primary life goal was to ensure the preservation of her ideas. The library was an integral part of that. If it was lost or dispersed, she felt, her ideas would be cut off at their roots.

Not long after the party, Kalin read Natural Capitalism, a book by Paul Hawkins, Amory Lovins and L. Hunter Lovins. It described the success of virtual companies which maintained no central headquarters but linked their staff and managers electronically. The first step in downsizing was to render her own reports onto a digital record, a task undertaken by Greg Ross, Kalin's computer wizard. The second stage was to transfer the electronic files and paper duplicates to the Desmarais Library at Laurentian University in Sudbury which made them accessible to students, researcher and, of course, to Kalin herself.

With the additional space this made available at Amelia Street, Kalin realized that she could take the next step towards becoming a virtual company if she gave up her Queen Street offices entirely and moved the business office to Amelia Street. Andrew Fyson, a microbial ecologist who had studied acidic lakes in Germany joined her there, along with Ross and Cassac. Also present in electronic spirit, if not in body, were her collaborators; Gunther Meinrath, a lecturer and researcher at the Technische Universität Bergakademie in Freiberg, and Bill Wheeler, an algal physiologist in California. According to the authors of Natural Capitalism, the transition to a home office would eliminate the need to transport 'heavy nuclei in the form of human beings' back and forth from home to office and would therefore "offer a welcome saving in time, fatigue, energy and cost."

Kalin's work on the Poela system in Germany and her attendance at meetings of the Institute for Freshwater Ecology and Inland

Fisheries in Berlin where she sat on the scientific advisory board, took her regularly to Germany invoking memories of her childhood. Her mother died in October, 2001, which brought her into closer contact with her family, her sister Ulla and her husband Martin in Saxeten, Switzerland, and her brother Andreas in Portugal. Over the years Kalin had brought the children of Ulla and Martin to North America on extended summer vacations. Those children were now young adults but the tradition passed easily to Vanessa and Denise, the young daughters of Arlinda and Andreas. With the transformation of Boojum into a virtual company, Kalin realized that there was no particular reason to restrict the 'heavy nuclei' of her own self to North America. Ulla and Martin lived in a house in Saxeten with a large attic which workmen transformed into an apartment and office for Kalin.

It seemed to Kalin that the mining industry was changing and she began to wonder if the time had come to retire. In the old days, Michelutti, Bell (both companies Falconbridge and INCO were purchases by international mining companies) and other earlier sponsors, took a chance on her, betting research dollars on her hunches and her conviction that with help and time biological systems could remediate mine wastes. Kalin and other biologists made their mark on the industry to the degree that companies were appointing 'vice-presidents of sustainability' and regulators were insisting that tailings be flooded, after decades during which they demanded that tailings be kept above ground. But 'wetlands' created overnight by bulldozers were a far cry from the carefully calibrated, specialized eco-systems that Kalin envisioned.

With South Bay closed to her, and the Link Lake and Key Lake projects winding down, Kalin was spending less time in the field. This, at least, had the fortuitous effect of allowing her to mine her own data for new insights. In a span of three years from 2003 to 2005 she and her co-authors published and presented nine major papers. One of these *Natural iron hydroxide precipitates: Their acid generation potential in ground water associated with tailings* was accepted for presentation at the March, 2006 International Conference on Acid Mine Drainage (ICARD), in St. Louis. The paper contained a detailed analysis of acid-generating microbes which had turned up, after four years in storage, in highly acidic ground water samples collected at South Bay. It provided a small but intriguing insight into the tenacity of acid generators; such small steps are the building blocks of science. Kalin was pleased and honored to be accepted at ICARD but she noted dismally that her talk was scheduled at 4 pm, the last time slot of the afternoon, which unfortunately conflicted with the opening of the conference bar. Her anxieties were confirmed when she was introduced to a sparse audience that seemed to be shrinking as fast as the line-ups at the exits allowed. She stood in the wings concentrating on her notes, and wondering if she had purposefully slighted. She took the podium still looking down. Finally, she looked up and began her talk.

"Ladies and gentlemen… holy shit."

The room was filled to capacity.

In the audience, listening to Kalin's talk was Roger St. Clair Smart, a research professor, at the Applied Centre for Structural and Synchotron Studies at the University of South Australia. Smart was the co-author of four papers presented at the conference, dealing with various aspects of treating and predicting acid generation, one of them on the formation of jarosite, one of the iron hydroxide precipitates that Kalin had discussed. Smart introduced himself to Kalin and the two of them quickly discovered common interests. When they ran out of time at the conference, Kalin invited Smart back to Toronto, where they spent the best part of 48 hours in non-stop conversation. She told him in particular about her on-going work with phosphate; the long-running drum experiment and the phosphate applications, now abandoned, at South Bay..

Kalin described the drum experiment in *Chemical Precipitation with Pyritic Waste Rock,* a paper that she was writing for the journal Hydrometallurgy. Throughout all of Boojum's ups and downs, its moves and transformations, Kalin had managed to hang onto seventeen 70-litre drums, some filled with acid generating waste rock from the Selbaie mine and half of those sprinkled with phosphate wastes from a mine in North Carolina. In December, 1992 in the glory days of the Billiton- Shell contract, Kalin had packed the drums and put them out into the weather – and the rain - on the balcony of her luxuriant new offices and labs on Queen Street; after the crash she moved them to the parking lot. After 989 days, she moved the drums into storage in the Queen Street basement. Four and a half years later, in September 1995, she put them back out into the weather in her backyard at Amelia. Through it all, the barrel discharges were faithfully collected and tested for pH, Eh and electrical conductivity. The results were intriguing and counterintuitive. In the first leg of the experiment, acid generation in the waste rocks containing phosphate – as compared to control drums containing waste rock and no phosphate – dropped 85%. Surprisingly, when the barrels were stored inside, and kept dry, the rocks continued to generate acidity. But when the rocks were returned outdoors in the second phase of the experiment, acidity dropped even further, for a total reduction of 90%.

Eventually the barrels were dissembled but research continued. Kalin shipped some of the rocks to the University of Windsor where she had been appointed adjunct professor and others to the University of Ottawa. Close microscopic analysis of the rock surfaces, at Ottawa, revealed a fine bio-film created by microbes which had sealed the pyrite from the rain, effectively stopping the discharge of acidity. This was a signal breakthrough and suggested to Kalin that she was on the verge of mining's Holy Grail, a cure for acid mine drainage. She was not the first to recognize that phosphate could be used to counter acid mine drainage but the strategy had previously been dismissed as being prohibitively expensive. Kalin's study suggested that far less phosphate was required to achieve the effect than had previously been estimated. Smart was fascinated by the work. Twenty kilograms of rock began another journey, this time from Windsor to Australia.

In April 2006, Kalin got an email from Glen Ware, the environmental advisor at the Zinifex Century Mine in Australia, the largest zinc mine in the world. Ware said the company was planning to implement a wetland system to treat AMD but that he had run into 'skepticism' about the effectiveness of wetlands in a semi-arid environment. Kalin almost laughed; a standing complaint of 'sceptics' in Canada ia that wetlands don't work in a cold climate. Ware said that a pilot system had generated anomalies; metal concentrations were down but sulphates were unexpectedly high. He included a package of data and wondered if she would be willing to get involved.

Kalin started packing.

In 2007, Boojum had reached the august age of 25 and by the end of the year, Kalin was preparing for her 60th birthday in Switzerland. She had good reason to be proud of the company's success as a virtual entity. Roger Smart, with a grant from AMIRA International Ltd, an independent research association sponsored by the mining industry, had confirmed the presence of biofilms on the rock surface. He also noted that the pyritic rock was still not generating acid. Suddenly the mining industry was taking a focused interest not only in the drum experiment but in all of Kalin's work with phosphate. Supported by AMIRA and Roger Smart, she applied for a Best in Science grant from the Ontario Ministry of the Environment and for further funding from AMIRA. The grants, if approved would, take her and other researchers back to the tailings deposit at South Bay and to sites in Elliot Lake and Sudbury where she had buried phosphate and manure in the conviction that this would lead to the creation of a layer of hardpan just below the tailings surface. Given the results of the drum experiment, it seemed likely that pyrite samples from the sites would be effectively sealed beneath a layer of biofilm. Further analysis and work in the field and laboratory would seek to determine the universality of phosphate induced biofilm formation.

Earlier in 2007 Kalin had given a lecture and conducted a workshop at the University of Coimbra. That, in turn had led to an invitation to visit the head offices of the Empressa Desenvolvimento Mineiro (EDM) the state holding company responsible for decommissioning inactive mines and that was having problems, in particular, cleaning up former uranium mines. The EDM also took a keen interest in the phosphate project. Coming up were scheduled talks in China and Chili in 2008. And the Zinifex work was going well so there would have to be a return trip to Australia.

Maybe, Kalin concluded, this wasn't such a good time to retire after all.

David Lees
December 2007

*   *   *

David Lees passed away in 2010. I miss him very much and will always be thankful for the great contribution he made to communicate our progress in science and its application of Ecological Engineering. Here, commemorating Boojum's 30th birthday, I will briefly describe the accomplishments achieved between 2008 and 2012, lacking of course the eloquence of David's writing.

Interest expressed by mining companies, consulting entities and regulatory bodies in ecological approaches to clean up acid mine drainage fades when it comes to dollars needed for field pilot tests. So, we were pleased to be invited to join the AMIRA project "P933 Evaluation of Passive Treatment Technologies' in Australia which ran through 2012. This work on biofilms and their prevention of pyrite oxidation has been received with mixed reviews.

As part of Boojum's educational mandate, I gave several short seminar courses and workshops at conferences in Santiago, Chile, Toronto, Montreal and Paris. One of these led to a connection with the Technische University Zurich, ZHAW, where I was hired to teach a portion of a course on Ecological Engineering to undergraduates.

Throughout the time period, usually after conferences, some mine executive or another would approach to ask Boojum's help with their mining problem. This would result in a trip to the mine site, a rush proposal and then waiting. None of these proposals were funded. Proposals during the period from 2008-2012 included the Pierina Mine in Peru, St. Andrews Goldfields in Ontario.

We continued our quest to clarify the mechanisms which would reduce sulphide oxidation with Dr. Brent Sleep at the Engineering Department of the University of Toronto. With Carlos Paulo who joined Boojum after the workshop at the University of Coimbra (Portugal), we gave several workshops and published papers in conference proceedings. Carlos is presently pursuing a PhD in geochemistry at the University of Toronto, with Dr. Maria Dittrich. Recently Prof. Dr. Wolfgang Sand, Aquatic Biotechnology in the Biofilm Centre of the Chemistry Department of the University of Duisburg-Essen has joined our quest for the reduction of sulphide oxidation. With Professor R. Warner, at the University of Kentucky we are testing the potential application of Ecological Engineering to coal mining effluents in the Appalachian Mountains. We have re-united with Dr. R. Scribalio, a Limnologist from the University of Purdue Biology/Chemistry Department, to assist with field work on that project.

We believe that by publishing the results of our work in book chapters, scientific papers and conference proceedings we can convince sceptical audiences that ecological processes can remediate acid mine drainage. To this end, we have published a number of our projects in book chapters, a progress of the ongoing research in journals and conferences proceedings.

I now live in Switzerland with my partner Dr. Lando Schlageter. I thank him for the many beautiful winter ski trips and summer hikes in the Swiss Alps, both activities I have never expected to experience again on my return from Canada. With him they bring great joy to my life and with him I am getting closer to retirement, away from the

computer. I hope he understands, as I am packing my suitcase again, that the projects with Professor Dr. Tangfu Xiao at the Institute of Geochemistry, Chinese Academy of Sciences are a very strong calling for me and the Boojum team.

Margarete Kalin

September 2012

Cover:
Above: The footsteps of an Ecological Engineer
Middle: Cattail transplant in Pre-Bog Acid Creek
Bottom: Horsetails on mine slimes at Levack

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