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Efficacy of Spanish River Carbonatite Applications into Agroecosystems
西班牙河碳酸盐岩在农业生态系统中的应用效果

Summary 概述

Introduction 介绍

Boreal Agrominerals Inc. (Boreal or the Company) produces and markets, under the labels "Spanish River Carbonatite" ("SRC") and "Volcanic Minerals Plus", a naturally occurring alkaline to ultramafic agromineral fertilizer and soil remediant for which there is growing demand as the world moves to more sustainable agricultureal practices. SRC is produced by Boreal from its 100% owned rare mineral deposit near Sudbury, Ontario.

博莱公司（简称博莱或公司）以"西班牙河碳酸盐岩"（简称"SRC"）和"火山矿物Plus（Volcanic Minerals Plus）"标签生产和销售天然产生的碱性到超镁铁质农药和土壤修复剂， 正如世界正在倾向更具可持续性的农业实践。 SRC由博莱从安大略省萨德伯里附近100％拥有的稀有矿藏中生产。

The efficacy of utilizing agrominerals, (rock dust), in agriculture to enhance crop production has been bolstered in recent years by earth science, geomicrobiology and soil microbiology discoveries. The application of agrominerals has been documented for a better part of 300 years with a strong correlation of positive soil and plant affects associated with ultramafic rocks.

近年来，地球科学、地质微生物学和土壤微生物学的发现为在农业中利用矿物农药（岩尘）提高作物产量提供了有力的支持。已有文献记载超过300多年的农业实践显示，与超镁铁质岩石密切相关的土壤和植物呈积极影响。

Renewed interest in the use of agrominerals to address soil health and plant nutrition has been the result of the following factors:

对于使用农药来解决土壤健康和植物营养问题重新产生兴趣是由以下因素造成的:

1. The organic agriculture movement, where the use of synthetic fertilizer is prohibited, instigated the investigation of alternate soil/plant fertility methodologies. This research led to a greater understanding of the role microorganisms play in cycling soil chemistry. 禁止使用合成肥料的有机农业运动推动了对替代土壤/植物肥力方法

的研究调查。这项研究使人们对微生物在土壤化学循环中的作用有了更深入的了解。

2. The increased awareness of soil microbe ecology has brought soil health to the forefront. The assessment and criteria of human activities on soil quality has not been defined. Yet it is generally accepted that agriculture has had a negative impact on soil quality through loss of organic matter and soil aggregation resulting in changes to soil microbial communities that ultimately affect nutrient cycling. On a greater scale it is becoming apparent that soil plays a major role in global chemical cycles, particularly carbon, nitrogen and silica. 随着人们对土壤微生物生态学认识的提高，土壤健康的问题日益突出。人类活动对于土壤质量的评价和标准尚未确定。然而人们普遍认为由于有机质和土壤团聚体的流失，农业对土壤质量产生了负面影响，导致土壤微生物群落发生变化，最终影响养分循环。在更大的范围内，土壤在全球化学循环中发挥着重要作用，特别是在碳、氮和二氧化硅。

3. The United States Environmental Protection Agency stated in 2000 that agricultural pollution was the leading source of water quality impacts on surveyed rivers and lakes, the second largest source of impairments to wetlands, and a major contributor to contamination of surveyed estuaries and ground water; major culprits being animal waste and fertilizer. 美国环境保护署2000年指出，农业污染是这些受调查的河流和湖泊水质影响的主要来源，是湿地受损的第二大来源，也是受调查河口和地下水污染的主要原因——其主要的罪魁祸首是动物粪便和肥料。

4. Energy use in agriculture; though the existing research into this question is far from clear there is general consensus that agriculture systems must become less reliant on non- renewable energy resources. Though requiring substantiation the use of agromineral resources within close proximity to established agriculture regions is sustainable and more efficient then refined mineral fertilizers. 农业中的能源使用——虽然对这一问题的现有研究远未明确，但普遍的共识是，农业系统必须减少对不可再生能源的依赖。虽然还需要证实，但在已建立的农业区附近使用农业矿物资源是可持续的，比精炼矿物肥料更加有效。

5. Ultramafic rocks have been cited for the potential to accelerate sequestration of atmospheric CO_2. Zhaoliang Song, (2012), goes further by suggesting that part of a strategy to accelerate the sequestration of atmospheric CO_2 through soil-plant systems can be accomplished with rock powder amendments. Katherine Keller, (2012), argues that agriculture has affected silica cycles through the depletion of phytolith[1] pools and the contribution of soil silicate minerals may become a key contributor to replenish depleted pools. 超镁铁质岩石被认为有可能加速大气中二氧化碳的封存。 宋照亮（Zhaoliang Song, 2012）进一步提出，通过岩粉修正可以实现部分通过土壤-植物系统加速大气二氧化碳封存的战略。 凯瑟琳·凯勒

（Katherine Keller，2012）认为，农业已经通过植硅体[1]库的消耗而影响了二氧化硅的循环，土壤硅酸盐矿物的贡献可能成为补充耗竭库的关键因素。

6. There is sufficient confirmation that nitrogen fertilizer stimulates microbial growth though enhanced use of soil organic carbon, (Westerman and Tucker 1974). Loss of organic matter through tillage and fertilizer application has resulted in organic matter at levels not adequate for the requirements of resting soil microbial populations, (Anderson and Domsch 1985). There is a growing body of research that is indicating that agromineral amendments and specific mineral types accelerate organic matter humification to the benefit of soil microbial communities. 有充分的证据表明，氮肥通过加强土壤有机碳的利用来刺激微生物生长(Westerman和Tucker，1974)。耕作和施肥造成的有机质流失已导致有机质含量不足以满足静息土壤微生物种群的需要(Anderson和Domsch，1985)。越来越多的研究表明，农用矿物改良剂和特定矿物类型加速了有机质的腐殖化，有利于土壤微生物群落。

Major scientific advances across a broad spectrum of disciplines have established that soil/plant/food/nutrition/health webs are infinitely more complex and interrelated than previously believed. Geoscience's major role in this new multi discipline science paradigm has yet to be substantively recognized. The global imperatives for environmental and ecological sustainability, along with safe and nutritious food will require the advanced capabilities of geoscience; in particular the study of the reactivity of unique naturally occurring minerals in various soil systems made available by complex biological/mineralogical interactions.

各种学科的主流科学进展已经证实，土壤/植物/食物/营养/健康网络比以前所认为的要更加复杂且相互关联。 地球科学的主要作用在新的多学科科学范例中尚未得到实质性认可。 全球对于环境和生态可持续性以及安全和营养食品迫切需求，这将依赖于地球科学的先进能力; 特别是通过复杂的生物/矿物相互作用研究各种土壤系统中独特的天然矿物的反应性。

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[1] "Phytoliths are rigid, microscopic structures made of silica, found in some plant tissues and persisting after the decay of the plant. These plants take up silica from the soil, whereupon it is deposited within different intracellular and extracellular structures of the plant. Phytoliths come in varying shapes and sizes. Although some use "phytolith" to refer to all mineral secretions by plants, it more commonly refers to siliceous plant remains." https://en.wikipedia.org/wiki/Phytolith "植硅体是由二氧化硅组成的坚硬的微观结构，在植物组织中发现并在植物衰败后持续存在。 这些植物从土壤中吸收二氧化硅，从而将其沉积在植物的不同细胞内和细胞外结构中。 植硅体有不同的形状和大小。 虽然有些人使用"植硅体"一词来指代植物的所有矿物质分泌物，但更多的是指硅质植物残体。"https://en.wikipedia.org/wiki/Phytolith

It is has been Boreal's mission from the onset to bring geoscience into the sustainable agriculture debate. Commencing in 1996 the founders of Boreal have attempted to demonstrate that the judicious use of ultramafic rocks, in this case SRC, with a carbon source, could stimulate soil biota to sequester atmospheric carbon and nitrogen, improve microbial habitat, supply mineral components that will enhance soil formation resulting in improved exchange properties and supply essential macro/micro nutrients. Validating this would result in a significant change in soil nitrogen management and an overall reduction in fertilizer use.

从地球科学开始到可持续农业辩论一直是博莱的使命。1996开始博莱的创始人试图证明如何明智地使用超镁铁质岩，在SRC有了碳源的情况下，便可促进土壤生物封存大气中的碳和氮，提高土壤微生物的生存环境，供应矿物成分会加强土壤的形成从而提高交换性能和供应必需的宏观/微观营养。如能证实这一点，将会使土壤氮素管理发生重大改善且使化肥的使用整体减少。

Boreal initiated its first academic partnership project in 2013, with Dr. Frédérique Guinel from Wilfrid Laurier University, to explore the effects of SRC. Findings from the project, funded by OCE's VIP-I program, showed that on-site plants were colonized by mycorrhizal fungi, indicating a symbiotic association between fungi and roots of the plants. Furthermore, legumes exhibited rhizobial nodules and sweetfern displayed actinorhizae, indicating the existence of several types of nitrogen-fixing bacteria in the deposit. In James Jones' recently submitted thesis, "Spanish River Carbonatite: Benefits and potential for use as a soil supplement in agriculture", SRC was evaluated to investigate the optimal concentration that most benefits the soil, microorganisms and plants; the impact of SRC on the important agricultural symbiosis between pea and rhizobia; and lastly the manner in which SRC is stored. A number of key observations such as' "plants were more photosynthetically active . . . ." and "plants grown with SRC gain more nitrogen per amount of carbon invested in nodulation . . . ." has resulted in James pursing his PhD thesis and bolstered Boreal's marketing efforts.

博莱公司（Boreal）于2013年与加拿大劳瑞尔大学（Wilfrid Laurier University）的Frédérique Guinel博士共同启动了首个学术合作项目，探索西班牙河碳酸盐岩（SRC）的影响。该项目由安大略省卓越中心（OCE）的VIP-I项目资助，结果显示，现场植物被菌根真菌侵染，表明真菌与植物根部之间存在共生关系。此外，豆科植物表现出根瘤菌结节，甜蕨表现出放线菌，表明存在多种类型的固氮细菌。在詹姆斯·琼斯（James Jones）最近提交的论文"西班牙河碳酸盐岩：作为农业土壤补充剂的效益和潜力"中，对西班牙河碳酸盐岩（SRC）进行了评估，以研究最有利于土壤、微生物和植物的最佳浓度； 西班牙河碳酸盐岩（SRC）对豌豆与根瘤菌重要农业共生的影响；最后是存储西班牙河碳酸盐岩（SRC）的方式。一些关键的观察结果，如"植物更具光合活性……"和"用西班牙河碳酸盐岩（SRC）生长的植物在结瘤中投入单位碳量可获得更多的氮……"致使詹姆斯完成他的博士论文，并带动博莱公司（Boreal）继续进行市场开拓。

In a recently-funded NSERC Engage project, Boreal will be identifying plant communities present in the natural SRC deposits and whether these plants may be accessing nutrients through association with soil microbes; in that context, the nutrient status of these plants and of their surrounding soil will be determined through the project collaboration with Dr. Petro Antunes from Algoma University. Currently Boreal, Wilfrid Laurier, Algoma and Waterloo Universities have submitted a grant application, “Microbial Community Analysis Related to Plant Growth Promotion by Spanish River Carbonatite” to the Ontario Genomics Institute.

在最近资助的加拿大自然科学和工程研究委员会（NSERC）参与项目中，博莱公司（Boreal）将确定存在于自然西班牙河碳酸盐岩（SRC）矿床中的植物群落以及这些植物是否可能通过与土壤微生物的关联获得营养物质; 在这种情况下，这些植物及其周围土壤的营养状况将通过与阿尔哥玛大学（Algoma University）的Petro Antunes博士合作确定。 目前博莱公司（Boreal）、加拿大劳瑞尔大学（Wilfrid Laurier）、阿尔哥玛大学（Algoma）和滑铁卢大学（Waterloo University）已向安大略基因组学研究所提交了一份“西班牙河碳酸盐岩促进植物生长的微生物群落分析”项目拨款申请。

Though Boreal has long recognized the relationship between microbes and minerals the current research has resulted in investigating opportunities that the company did not consider. As well as synergistic relationships with carbon companies Boreal has also worked closely with biological companies such as Mikro-Tek and Earth Alive Clean Technologies. Today every multi-national biotech company has acquired companies that have developed microbe symbiant products for sustainable agriculture markets. The possibility that the unique geological footprint of the SRC complex could produce unique soil microbial communities is an important market opportunity. The current research project represents a living laboratory where the study of distinct evolutionary changes in soil biota is occurring as a result of the inherent geological landscape.

尽管博莱早已认识到微生物与矿物质之间的关系，但目前的研究也创造了一些公司未曾考虑到的调查机会。 除与碳公司的协作关系外，博莱还与Mikro-Tek和Earth Alive Clean Technologies等生物公司有着密切合作。如今每个跨国生物技术公司都收购了为可持续农业市场开发微生物共生产品的公司。 SRC复合物独特的地质足迹有可能产生独特的土壤微生物群落，这是一个重要的市场机会。 目前的研究项目代表了一个活生生的实验室研究土壤生物群不同的演变是由于固有的地质景观而发生的。

To address the geoscience aspect of the SRC complex and the effects of SRC amendments on geochemical cycling of N, Si, and P in soils Boreal has begun to collaborate with Drs. Corcoran and Webb from the Department of Earth Sciences at Western University to study the geology of the deposit. The scientists have agreed to put together a NSERC Engage and subsequently a NSERC-CRD grant application to hire MSc students.

为了解决西班牙河碳酸盐岩（SRC）复合体的地球科学问题以及西班牙河碳酸盐岩（SRC）改良剂对土壤中氮、硅和磷（N, Si, and P）地球化学循环的影响，博莱公司（Boreal）已经开始与西部大学（Western University）地球科学系的Corcoran和Webb博士合作，研究矿床的地质情况。 科学家们已同意将加拿大自然科学和工程研究委员会参与项目（NSERC Engage）和加拿大自然科学和工程研究委员会协作研发部（NSERC-CRD）授予的资金申请放在一起来聘请科学硕士研究生。

It is the goal of Boreal to substantiate through collaborative scientific research and a long term on-farm trial with industry partners the green mining economic opportunity. Boreal's long-term strategy is to build on the company's first asset, the SRC deposit, which will facilitate the creation of a Canadian agromineral company that not only profitably exploits mine waste streams but follows in the long tradition of Canadian mining excellence of applied geoscience technology.

博莱公司的目标是通过与业界伙伴合作科学研究并进行的长期农场试验证实绿色矿业的经济价值。 博莱的长期战略是建立在公司的第一资产——SRC矿床上，这将有助于树立一个双赢的加拿大农业公司，此公司不仅可以盈利地开采矿山废物流，并且遵循传统悠久的加拿大采矿业与其卓越的应用地球科学技术。

Background 背景

The Spanish River Carbonatite Complex 西班牙河碳酸盐岩复合体

Alkaline Rocks 碱性岩石

Amongst geologists no other rocks have provoked such interest as the alkaline or alkalic group. This fascination is out of proportion to the number of occurrences where less than 1% of igneous rocks are classified as alkalic and yet one third of all rock names are alkaline; a total of more than 250. An explanation of their unique suite of minerals and incredible diversity of chemical compositions exceeds the boundaries of present petrogenic theories, (Currie 1978). Though the origins of alkaline rocks is fraught with debate generally excepted conditions to formation are proximity to crustal plate boundaries, a strong association with tholeiitic basalts[2] and the very deep source of parent magma; often greater than 50 km.

对地质学家而言，没有任何其他的岩石能像碱性或碱性组岩石一样引起他们的兴趣。火成岩仅有不到1％被分类为碱性，这与它们的魅力不成比例，而所有岩石中有三分之一是碱性的——总共超过250种。其独特的矿物组合和不可思议的化学成分多样性已超出了现有的成岩理论界限（Currie，1978）。 虽然碱性岩的起源充满了争议，但除了接近地壳板块边界这一成因外，其形成的条件通常是个例外，与拉斑玄武岩[2]和母岩浆的深源相关联——通常大于50公里。

Alkalic rocks are characterized by concentrations of alkali metals greater than normally found in igneous rocks. These ultramafic, (ultrabasic) occurrences chemically have low silica content, (less than 45%). Ultramafic rocks as well as low in silica are rich in magnesium and iron minerals, (normally greater than 90%). Ultrabasic (alkalic) are rocks that are low in silica and not enriched in magnesium and iron minerals; the best example being carbonatites. Carbonatites are often referred to as complexes because the mineral zonation is ringed; alternating from alkalic, (ultrabasic) to ultramafic.

碱性岩石的特点是其碱性金属的浓度比火成岩中常见的要高。 这些超镁铁质发生化学反应具有较低的二氧化硅含量（小于45％）。 超镁铁质岩石和低硅质岩石都含有丰富的镁和铁矿物质（通常大于90％）。 超碱（Ultrabasic）是二氧化硅含量低且不富含镁和铁矿物的岩石——最好的例子是碳酸盐岩。 碳酸岩通常为复合体，因为矿物分带是环状的——由碱性和超镁铁质交替。

Figure: 1 Igneous Rock Classifications 火成岩分类

Figure: 1 Igneous Rock Classifications

(pg. 137 Principles of Mineralogy, Second Edition)

*Highly Reactive   *Non-reactive

	Ultramafic	Mafic	Intermediate	Felsic
Weight % SiO_2	45	52	66	

** Based on current geoscience and geomicrobiology publications evaluating rates of mineral dissolution. Further scientific substantiation is required.*

2 Tholeiitic basalt is one of two major mafic magma divisions. The distinguishing characteristic from the second group, calc-alkaline magma series, is the redox state of the basal; tholeiitic magmas are reduced while calc-alkaline are oxidized. 拉斑玄武岩是两个主要的镁铁质岩浆分裂之一。 与第二组钙碱性岩浆系列的区别特征是基底的氧化还原状态; 随着钙碱被氧化，拉斑玄武质岩浆减少。

Mineralogical and chemical characteristics of alkalic rocks highlighted by Dr. R.P. Sage, Ontario Geological Survey, which impart distinct changes to mineralogy and weathering properties, are:

安大略省地质调查局的R.P. Sage博士强调了碱性岩石的矿物学和化学特征，突出表现了矿物学和风化特性的明显变化有：

1. Chemical and mineralogical diversity; 化学和矿物学多样性;

2. Disproportionate concentration of hydrolysable bases, (Ca, Na, Mg, K); 不成比例的水解碱浓度（钙、钠、镁、钾）；

3. Volatiles (H2O, CO2); 挥发物（水、二氧化碳）；

4. Lithophile elements (a strong affinity for oxygen, having a greater free energy of oxidation); 亲石元素（对氧气有很强的亲和力，具有较大的氧化自由能）；

5. Primary clay minerals; 原生粘土矿物;

6. Anomalous rare earth content. 稀土含量异常。

The inherent properties found in alkaline and ultramafic rock occurrences have pronounced effects on the weathering rate of rock forming minerals present, resulting secondary mineralization, chemical constituents required by the biosphere and a greater understanding of the mechanisms that cycle this essential life chemistry has increased scientific interest in these formations. Current geomicrobiology research is documenting that terrestrial cycles of silicon and carbon driven by plants and soil organisms play a vital role in the regulation of atmospheric CO_2. The identified mechanisms are: (i) mineral weathering facilitated by life, (ii) the formation of phytoliths, (iii) accumulation of secondary clay and (iv) protection of soil organic carbon through aggregation. The role of silicate mineral weathering in carbon cycles is bringing the importance of ultramfic rock formations to the forefront of these life mediated processes. Researchers at the U.S. Geological Survey developed a digital geologic database of ultramafic rocks in the conterminous United States that have been deemed suitable for mineral CO_2 sequestration. This phenomena is due to rapid silicate mineral weathering characteristics, partially the result of ultramafic rock redox characteristics, (high state of reduction), and composite mineral crystal structure that is preferential to microbial attack.

碱性岩和超镁铁岩中发现的固有特性对岩石形成矿物的风化速率有显着影响，导致次生矿化，生物圈所需的化学成分以及对这种基本生命化学循环机制的更深入理解，增加了对它们的科学兴趣。目前的地质微生物学研究证明，由植物和土壤生物驱动的硅和碳的陆地循环在调节大气中的二氧化碳方面发挥着重要作用。其中已确定的机制有:（i）生命促进的矿物风化（ii）植硅体的形成（iii）次生粘土的积累以及（iv）通过聚集对土壤有机碳的保护。硅酸盐矿物风化在碳循环中起到的作用是将超镁铁岩层推到生命介导过程的最显著地位。美国地质调查局的研究人员开发了一种数码地质数据库，其中美国的超镁铁质岩石被认为可适用于矿物二氧化碳的封存（碳汇）。这种现象归因于快速硅酸盐矿物的风化特征，其中部分归因于超镁铁质岩石的氧化还原特征（高还原状态）以及优先于微生物侵蚀的复合矿物的晶体结构。

Volcanic and Igneous Rock Classifications

Rock Type	***Ultramafic***	***Mafic***	***Intermediate***	***To Felsic***	***Felsic***
Volcanic rocks	Komatite	Basalt	Andesite	Dacite	Rhyolite
Sub-volcanic rocks	Kimberlite * Carbonatite	Diabase	Aplite-	Pegmatite	
Plutonic rocks	Lamproite Peridotite	Gabbro	Diorite	Granodiorite	Granite
General Characterisitcs					
Mineral Constituents	Numerous		Intermediate	Few	Fewest
Reactivity	Very High	High	Intermediate	Low	Lowest
Physical Properties (including magnetism, paramagnetism electromagnetism and gravity)	Very High	High	Intermediate	Low	Lowest

Overview of Carbonatite Complexes 碳酸盐复合体综述

"Haunted for decades by the ghost of the theory of limestone assimilation, petrologists seeking to explain the origin of these rocks have now successfully exorcised the phantom by invoking the blessing of carbonatites, limestones of igneous origin." E. Wm. Heinrich, The Geology of Carbonatites, Preface vii, 1996.

"石灰岩同化理论的鬼魂已经困扰了大家数十年，而不断寻找这些岩石起源答案的岩石学家们如今借着碳酸岩（火成岩起源的灰岩）的祝福成功地驱散了幻影。"——E. Wm. Heinrich，碳酸岩地质学，前言vii，1996。

Until the 1950's the prevailing belief was that calcite could not crystallize from the mantle, but was incorporated into magma from material originating from limestone beds via hydrothermal solutions, (water in the magma). The primary argument for the non-magmatic origin of carbonatite was that the melting temperature of calcite is too high (i.e., ~1300°C at 1 kbar). However, Wyllie and Tuttle (1960, J. Pet, vol 1, pp 1-46) showed that the melting temperature of calcite is suppressed to ~620°C in the presence of H_2O vapour. Observations of the eruption of natrocarbonatite (dominated by sodium carbonate) from Oldoinyo Lengai in the early 1960's lay to rest any doubts of the non-magmatic origin of this rock type. The Oldoinyo Lengai lavas erupt at 500-600 C°, lower than any other lava on earth.

一直到二十世纪五十年代，人们普遍认为方解石不能从地幔中结晶，而是通过热溶液（岩浆中的水）从石灰岩层中产生的岩浆中加入到岩浆中。 碳酸岩的非岩浆来源的主要论点是方解石的熔化温度过高（即在1kbar时大约1300°C）。 然而，Wyllie和Tuttle（1960，J. Pet，第1卷，第1-46页）表示，在水蒸汽存在下，方解石的熔融温度被抑制到大约620°C。 20世纪60年代初期在伦盖火山（Oldoinyo Lengai）观察到碳酸钠盐岩（ natrocarbonatite，以碳酸钠为主）的喷发打破了对这种类型岩石非岩浆成因的疑虑。 伦盖火山熔岩在500-600°C喷发，低于地球上任何其它熔岩。

Today Earth science researchers are recognizing that it is this unique volcanism and the associated African Rift valley, host to numerous alkaline rock occurrences, which have had a significant contribution to the Serengeti Plains soil development. This nutrient rich grassland hosts the largest land mammal migration on Earth.

今天，地球科学研究人员正认识到，正是这种独特的火山作用以及与之相关的非洲裂谷，形成了大量的碱性岩石，对塞伦盖蒂平原（the Serengeti Plains）的土壤发育作出了重大贡献。 这个营养丰富的草原上有着地球上最大的陆地哺乳动物迁徙。

Carbonatite complexes represent approximately 30% of alkaline rock occurrences. Carbonatite is generally accepted to be intrusive and extrusive carbonate rocks associated with alkaline igneous activity. Author E. Wm. Heinrich in "Geology of Carbonatites" for descriptive purposes defines carbonatite "as a carbonate-rich rock of apparent magmatic derivation or descent." For our purposes Spanish River Carbonatite, (SRC), is described as a magmatic pipe whose age and genesis is coincident with and related to the Sudbury Basin magmatic event. "The Dictionary of Geological Terms" cautions that the term carbonatite is not synonymous with limestone. In fact all limestone mined in the province are either sedimentary or metamorphic in origin and this genetic difference is at the heart of what makes carbonatites unique. The adopted nomenclature used is from Dr. R.P. Sage of the Ontario Geological Survey in his series of studies of Ontario carbonatite complexes.

碳酸盐岩复合体代表了约30％的碱性岩石。 碳酸岩通常被认为是与碱性火成岩活动相关的侵入性和喷出性碳酸盐岩。 作者E. Wm. Heinrich在《碳酸岩地质学》中将碳酸盐岩定义描述成"富含碳酸盐的、有明显衍生或下降岩浆的岩石"。我们将西班牙碳酸盐

岩（SRC）描述为岩浆管，其年代与萨德伯里盆地岩浆事件重合，且成因与之相关。《地质术语词典》提醒到，术语碳酸盐不是石灰石的代名词。 事实上，在该省开采的所有石灰石都是原产地沉积或变质的，这种遗传差异是碳酸岩独特性的核心。其采用的命名法来自安大略省地质调查局的R.P. Sage博士在他的一系列关于安大略碳酸盐岩复合体的研究。

"Sovite. A carbonatite rock composed of 50 percent or more calcite. Various mineralogic modifiers are used to classify the sovite, for example apatite-magnetite sovite, olivine-amphibole sovite, etc."

"黑云碳酸岩——由*50%*或更多的方解石组成的碳酸盐岩。 多种矿物学改性剂被用于黑云碳酸岩的分类，例如磷灰石—磁铁矿苏打，橄榄石—角闪石等。"

Carbonatite complexes can be both very simple to the most complex mineralogy types of igneous rocks. Consisting almost entirely of calcite and dolomite to a variety of carbonates accompanied by silicates, phosphates, sulfates, iron oxides, RE carbonates, sulfides, fluorides and niobium oxide minerals. In excess of 50 minerals have been found in carbonatites (Pecora, 1956). Dr. Sage commented during a site visit to the Spanish River Carbonatite quarry, stated, "that after years of publishing his geologic research of identified carbonatites in Ontario he circulated an internal O.G.S. memo regarding the ability of these unique rock occurrences to be used as a natural fertilizer". This comment was in response to the changes in growth patterns associated with these geological events. Today, as well as, distinct magnetic and electromagnetic signature carbonatites are found through evaluating vegetative patterns overlying complex occurrences.

碳酸盐岩复合体涵盖了最简单到最复杂的火成岩矿物学类型。 几乎完全由方解石和白云石组成的各种碳酸盐伴生着硅酸盐、磷酸盐、硫酸盐、氧化铁、稀土碳酸盐、硫化物、氟化物和氧化铌矿物。 在碳酸岩中发现了超过50种矿物（Pecora，1956）。 Sage博士在对西班牙河碳酸盐岩采石场进行实地考察时评论说："在他发布安大略省确定的碳酸岩的地质研究多年以后，他发布了一份内部O.G.S. 关于这些独特的岩石事件被用作天然肥料的能力的备忘录"。 这一评论是为了回应与这些地质事件有关的增长模式的变化。 今天，以及通过评估覆盖复杂事件的植物模式发现不同的磁性和电磁签名碳酸岩。

The Origin of the Spanish River Carbonatite 西班牙河碳酸岩的起源

The birth of SRC Complex is distinctive amongst unique carbonatites. A rock, 10 kilometres, (6 miles), in diameter and travelling at approximately 143,000 kilometres per hour, (89,000 mph), impacted the Earth. The resulting catastrophic shock wave resulted in a plume of super-heated rock, from the deepest part of the crust, catapulting into the Earth's early atmosphere; only to return under the pull of gravity in a great splat; extensively turning the crust inside out. After the dust had settled, a hole that was originally 250 kilometres, (155 miles in diameter), was created, a molten rock lake that was three times the size of the current Yellowstone caldera. Yet, out of this Hades, geoscientists theorize that, similar to what occurred in Yellowstone, the vast network of hydrothermal vents and complexity of mineral constituents created the very conditions necessary for life.

SRC复合体的诞生在所有特别的碳酸岩中都可说是独特的。 一块直径10公里（6英里）的岩石以每小时14.3万公里（89,000英里/小时）的速度行进，撞击了地球。 由此产生的灾难性冲击波产生了一层超热岩石，从地壳的最深部分弹射到地球早期的大气中，在重力的作用下泼溅回地表，大部分的外壳从内部翻转。 尘埃落定后，产生了一个原始为250公里（155英里直径）的洞，这个熔岩湖是目前黄石火山口的三倍大。 然而在地幔中，地质学家们推断，类似于黄石发生的事情，巨大的热液喷口网络和矿物成分的复杂性创造了生命所必需的条件。

This catastrophe, referred to as the Sudbury Event, is the leading hypothesis for the genesis of the Sudbury nickel basin and fortuitously, the SRC Complex. The modern surface of the deposit consists of the very roots of the original outflow of igneous material. These remnants of the impact site are known as the Sudbury Basin, and this deep magma resulted in the deposition of one of the richest nickel deposits in the world. The SRC deposit is located on the outer perimeter of the Sudbury Basin. Referred to as a pipe the igneous intrusion is comprised of calcium, magnesium, silica, phosphorous, potassium and iron minerals.

这场灾难，被称为萨德伯里事件，是萨德伯里镍盆地成因的首要推测，同样偶然的形成了SRC复合体。 矿床的现代表面由原始流出的火成物根源组成。 这些冲击地点的残余部分被称为萨德伯里盆地，这种深部岩浆造成了世界上最富有的镍矿床之一的沉积。 SRC矿床位于萨德伯里盆地的外围。 火成岩侵入管道是由钙，镁，二氧化硅，磷，钾和铁矿物组成的。

The Geology and Mineralogy of the Spanish River Carbonatite 西班牙河碳酸岩的地质和矿物学

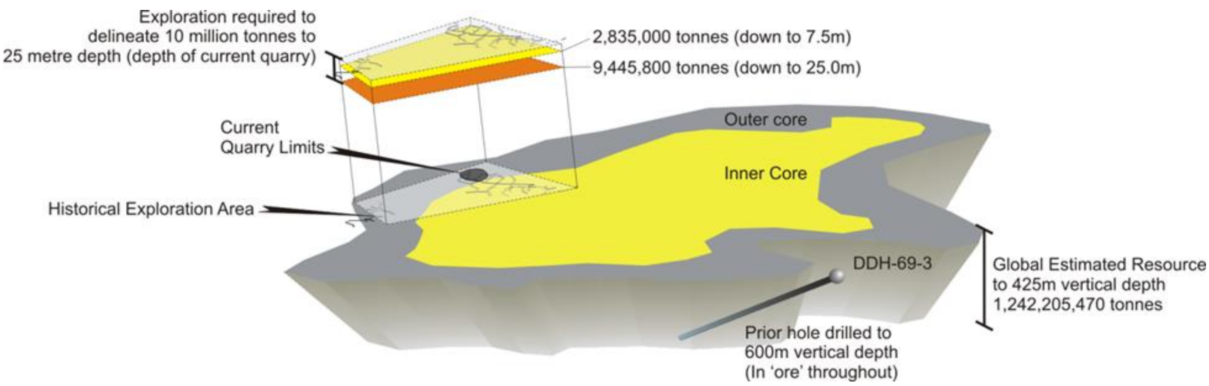
The Spanish River Carbonatite (SRC) is comprised of four major rock units defined by mineral composition. These divisions are rocks with high silicate content within the outer core comprised of silicocarbonatite, ijolite and pyroxenite phases and lower-silicate carbonatite, sovite, occurring towards the core of the complex, (Sage 1987). All major rock units are quarried together to produce current SRC product predominated by biotite sovite and ijolite where much of the biotite has been weathered to vermiculite.

西班牙河碳酸盐岩（SRC）按矿物成分由四个主要岩石单元组成。 它们的区别在于外部岩芯中含有高硅酸盐含量的岩石，它由硅碳酸盐岩，蛭石和辉石岩相和低硅酸盐碳酸盐岩（硅酸盐岩）组成，发生在复合岩核心（Sage，1987）。 所有主要的岩石单元在一起被开采以生产当前的SRC产品——主要是黑云母苏云石和蛭石，其中大部分黑云母已经风化成蛭石。

Based on past and current geological mapping, the ground magnetometer survey, seismic data, diamond drilling, reverse-circulation drilling and the 1996-trenching program a global resource was estimated for the Spanish River Carbonatite Complex. The purpose of this un-vetted, (43-101 unsubstantiated)[3], calculation was to demonstrate the size of complex and aid in developing long-term mining and processing infrastructure to supply calcite, biotite, pyroxene, vermiculite and apatite to the growing sustainable agriculture market.

根据过去及现在的地质图、地面磁力计勘测、地震数据、钻石钻探、反循环钻探以及1996槽探计划，对西班牙河碳酸盐岩复合体进行了全球资源估算。 这项未经审核的（43-101未经证实）[3]计算的目的是为了证明复合体的规模，并协助开发长期采矿及加工基础设施，为不断发展的可持续农业提供方解石、黑云母、辉石、蛭石和磷灰石市场。

Figure: 3 Surface Schematic of Spanish River Carbonatite Complex (Not to Scale) 西班牙河碳酸盐岩复合体表面示意图（不按比例）



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[3] National Instrument 43-101 (the "NI 43-101" or the "NI") is a national instrument for the Standards of Disclosure for Mineral Projects within Canada. 国家文书 43-101（"NI 43-101"或"NI"）是披露加拿大矿产项目标准的国家文书。

Table: 1 Spanish River Carbonatite Potential Global Resource 西班牙河碳酸盐岩潜在全球资源

Resource Estimate of Spanish River Carbonatite Complex

(Un-vetted global estimate prepared by Agriculture Mineral Prospectors Inc., 1999)

Trenching, Geological Mapping, Seismic Survey and Drill Hole 69-3
has approximated size and shape of high calcium carbonate facies
of Spanish River Complex

Block	Area	Depth	Volume	S.G.	Tonnes
Spanish River Carbonatite	1,082,532	425	460,076,100	2.7	1,242,205,470
Calcite Resource 65%					807,433,556
Apatite Resource 5%					62,110,274
Biotite Resource 5%					62,110,274
Magnetite Resource 5%					62,110,274

1)ddh69-3 intersected inner core at a vertical depth of 950 metres
and over a true width of 178 metres
2)seismic survey and trenching program at the road zone estimate
width of inner core at 570 metres
3)geological mapping and magnetic survey estimate length
deposit at 1500 metres
4)calculated area is based on all available information and topographical relief
5)depth taken at 1/2 the depth of ddh69-3
6) S.G. of calcite used
7)estimates of calcium, biotite and apatite resource based on assay results of trenching

Current Ore Resource of Spanish River Dense Layer

(43-101 vetted reserve prepared by Gary K. Smith, Devon Corp., 2012)

Trenching, Geological Mapping, Geochemistry and Seismic Survey

Block	Area	Depth	Volume	S.G.	Tonnes
Dense Layer	188,916	7.5	1,416,870	2.0	2,833,740
Calcium Resource 90%					2,550,366
Biotite Resource 5%					141,687
Apatite Resource 5%					141,687

1) siesmic survey and trenching program estimate dense layer depth to 7.5 metres
2) porosity of dense layer discounts S.G. to 2.0
3) estimates of calcium, biotite and apatite resource based on assay results of trenching
4) area covered by trenching only included in resource estimate
5) dimensions of area are 800 metres long by 270 metres wide

Mineralogy of the Spanish River Carbonatite Complex 西班牙河碳酸盐岩的矿物学

The modal composition of the SRC deposit is 50 to 100% calcite, 0 to 20% pyroxenes', 0 to 15% apatite and 0 to 20 per cent biotite. Currently quarried mineral composition is 60% calcite, 15% Biotite/Vermiculite, 12% apatite, 7% pyroxenes' and 6% accessory minerals.

SRC沉积物的组成模式为50至100％的方解石、0至20％的辉石、0至15％的磷灰石和0至20％的黑云母。 目前开采的矿物成分为60％方解石、15％黑云母/蛭石、12％磷灰石、7％辉石以及6％辅助矿物质。

The growing awareness of the need to increase the nutritional content of food and enhance soil quality, in agriculture, describes the need for minerals to achieve sustainable food production. The use of the word “minerals” in this context refers to the chemical elements that are required by living organisms; commonly referred to as dietary or mineral nutrients. Unfortunately, it is in the same context that soil amendments tend to be evaluated. Described as essential and trace minerals, the evaluation of an agromineral is misleadingly by measuring its elemental constituents alone; misleading, because virtually all Earthly compounds contain all or most of the elements in the periodic table. Evaluating the chemistry of rocks alone, therefore, does not indicate the level of their agronomic benefit; an analytic report supplies only the elemental composition not the mineral constituents. The rate at which a mineral weathers or imparts catalytic affects within the soil system is a function of mineral genesis and crystal behaviour. Were the physical properties of a mineral has a pronounced effect on the redox equation equally important is the minerals physical properties.

农业范围中，有越来越多的人认识到有必要提高食物的营养含量和提高土壤质量，这说明需要矿物来实现可持续的粮食生产。在这种情况下使用“矿物”一词指的是生物体所需的化学元素，通常为食物或矿物质营养素。可惜的是，在同等情况下，土壤改良剂往往被低估。作为必需及微量矿物质，农用矿物由于其元素成分是单独测量的，对它的评估具有误导性。因为几乎所有的地球化合物都含有元素周期表中的全部或大部分元素。因此，单独评估岩石的化学性质并不能表明其农艺效益的水平;分析报告仅提供元素组成而非矿物成分。矿物风化的速率催化作用在土壤系统内的影响是矿物成因和晶体行为的作用。如果矿物的物理性质对氧化还原方程有显著的影响，那么矿物的物理性质同样重要。

Calcite (Calcium Carbonate, $CaCO_3$) 方解石（碳酸钙，碳酸钙）

For the purpose of this document the term “reactive” is used to describe the rate at which natural rock forming minerals weather in the soil system. Even when comparing mineralogical and geological similar deposits, each deposit carries its own unique physical and chemical properties, which will either accelerate or hinder the natural weathering process. In the case mineral weathering within the soil profile dissolution is substantially accelerated by microbe and plant exudates occurring in the rhizosphere[4].

就本文而言，术语“反应性”用于描述天然岩石形成矿物在土壤系统中风化的速率。 即使在比较矿物学和地质类似的矿床时，每个矿床都有其独特的物理和化学特性，这会加速或阻碍自然风化过程。 在土壤剖面溶蚀的矿物风化过程中，由于根际中发生的微生物和植物渗出物，风化过程显着加速[4]。

[4] The rhizosphere is the region of the soil that is directly affected by root exudates and associated microbe communities. 根际是直接受根分泌物和相关微生物群落影响的土壤区域。

Flu gas operators routinely test calcium carbonate sources for reactivity and purchase reactive black limestone from Michigan on this basis, (Veldhuyzen, personal correspondence, 2002). Nelson R. Shaffer, a research scientist with the “Indiana Geological Survey” at Indiana University has spent several years studying the chemical, mineralogical and physical properties of Indiana limestone deposits to determine what makes some limestone more effective in scrubbers then others. Shaffer’s work shows that similar limestone deposits can differ by more than a thousand percent in the amount of sulfur dioxide they can absorb. Shaffer describes the effectiveness of limestone in terms of reactivity, “as the measurement of how rapidly and completely a particular limestone absorbs sulfur dioxide”. Physical factors that significantly affect reactivity are porosity and hardness. Chemical properties such as magnesium will have an effect on reactivity. Mineralogy and crystal structure is currently not used to evaluate different agriculture lime resources. Where calcium magnesium carbonates demonstrate a higher neutralizing index due to the capability of dolomites chemical formula, ($CaMg(CO_3)_2$), to neutralize a higher quantity of acid compounds yet is unable to achieve neutralizing potential because of inherent poor reactivity properties.

烟气运营商经常测试碳酸钙来源，在此基础上从密歇根购买活性黑灰（Veldhuyzen，个人通信，2002）。印第安那大学“印第安娜地质调查”科学家谢弗（NelsonR.Shaffer）花了数年时间研究印第安娜石灰石的化学、矿物和物理性能，确定什么使某些石灰石在洗涤器中更有效。谢弗的研究表明，类似的石灰石沉积在二氧化硫吸收量上可能相差十倍。谢弗表述了在反应性方面石灰石的有效性，“通过测量一种特殊的石灰石如何迅速和完全的吸收二氧化硫”。显著影响反应性的物理因素是气孔和硬度。镁等化学性质会对反应性产生影响。矿物学和晶体结构目前不用于评估不同的农业石灰资源。由于白云石化学配方（$CaMg(CO_3)_2$）的能力，钙镁碳酸盐表现出较高的中和指数，因此中和较大量的酸化合物由于固有的较差反应性性质而无法实现中和潜力。

Beyond the objective of addressing soil pH calcium’s role in microbial/plant/soil dynamics is critical at all levels of the foodweb[5]. As well as temporarily adjusting soil pH calcium has been cited for the following agronomic benefits.

除解决土壤pH值问题之外，钙在微生物/植物/土壤动力学中的作用对于食物网[5]的各个层级都是至关重要的。 除了能暂时调节土壤pH值，钙还被引用于下列农业效益。

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[5] A complex of interrelated food chains, (American Heritage® Dictionary of the English Language, Fifth Edition); A combination of food chains that integrate to form a network, (Collins English Dictionary); A group of interrelated food chains in a particular ecological community, (The American Heritage® Dictionary of Student Science, Second Edition). 一组相互关联的食物链（美国传统®英语词典，第五版）；一个的食物链组合整合以形成网络（Collins English Dictionary）；在一个特定的生态社区中的一组相互关联的食物链（美国传统®学生科学词典，第二版）。

1. Controls the physiological balance of plant nutrients in the soil. 控制土壤中植物营养物质的生理平衡。

2. Direct Source of Plant Nutrients - calcium is an essential macro plant nutrient and is supplied directly to support plant life. 植物营养素的直接来源——钙是一种必需的宏观植物营养素，并直接供应以支持植物生命。

3. Calcium in pectate holds cellulose together. 果胶中的钙将纤维素结合在一起。

4. Adequate calcium is crucial for plants developing proper cell wall membranes. 充足的钙对植物发育适当的细胞壁膜至关重要。

5. Plants use calcium as a signaling messenger, like neurons in humans & animal life. 植物使用钙作为信号传递者，就像人类和动物生命中的神经元一样。

6. Improved Soil Tilth - addition of calcium renders the soil more workable and friable. Fine, colloidal clays that dry into large clods (hard panned clay) are broken up and pulverized more easily. Liming materials exert a flocculating action on fine clays. 改善土壤耕层——钙的添加使土壤更易于耕作且更易碎。干燥成大土块（硬质粘土）的细小胶体粘土裂开并更容易成粉。石灰材料对细粘土发挥絮凝作用。

7. Provides Source of Trace Elements – calcium sources, such as SRC, is a fruitful source of many trace elements that are important to plant growth. In some crops it is vital. Most important among these elements that are prevalent in many lime sources are manganese, iron, copper, zinc, boron and molybdenum. 提供微量元素的来源——钙源（如SRC）是许多对植物生长很重要的微量元素的丰富来源。在一些作物中，这是至关重要的。在许多石灰来源中普遍存在的这些元素里最重要的是锰、铁、铜、锌、硼和钼。

8. Reduces the Toxicity of Several Soil Constituents and Combinations. Calcium carbonate is often cited as an additive to correct soil toxicity problems. 降低几种土壤成分和组合的毒性。通常引用碳酸钙作为纠正土壤毒性问题的添加剂。

9. Nutrition and Storage - Adequate calcium will produce crops that will store better. 营养和储存——充足的钙会产生更好储存的作物。

The role of organic matter in soil formation and fertility is paramount. What is little understood and is attracting the attention of many researchers is the clarification of geographical characteristics of humus formation that are determined by the pre-existing conditions of soil formation. One of best summaries of this subject was presented by the Russian scientist Kononova, "Humus of Virgin and Cultivated Soils". Kononova's investigation of soils in the USSR highlights current understanding of these processes. The conditions of humus formation are affected by vegetation, hydrothermal regime, nature of biological activity and parent material. They are reflected in nitrogen and humus content, distribution within the soil profile and the consistent differences in the properties of humus substances. Decaying constituents of the vegetation cover is the main source of soil humus and is the main source of energy for many microorganisms. The formation of humus is largely due to their activities. The total reserves of aerial and root system biomass varies greatly depending on vegetation, climatic conditions and soil properties.

有机质在土壤形成和施肥中的作用是至关重要的。很少有人了解且引起很多研究人员的注意的是，澄清由先前存在的土壤形成条件决定的腐殖质形成的地理特征。俄罗斯科学家科诺诺娃（Kononova）提出了这一主题的最佳综述之一："未被开垦土壤和耕作土壤的腐殖质"。 科诺诺娃对苏联土壤的调查突出了当下对这些过程的理解。腐殖质形成的条件受植被、水热条件、生物活性的性质和母质影响。它们反映在氮和腐殖质含量上、土壤剖面内的分布以及腐殖质物质性质的一致性差异。腐烂的植被覆盖物是土壤腐殖质的主要来源，也是许多微生物能量的主要来源。腐殖质的形成主要是由于它们的活动。根据植被、气候条件和土壤性质，空中和根系生物量的总储量变化很大。

Kononava concluded that there is no direct relationship between soil humus content and total reserve of plant biomass. Plant cover is only one of the factors controlling soil formation and the accumulation of humus. In various studies, the influence of parent material on soil formation, type and content of humus formation has been investigated. The incorporation of calcium from parent rock into the biological cycle promoted the accumulation of humus and the preferential formation of humic acids in the upper biogenic soil layer. In cultivated soils, lime plays an important role in the transformation of organic matter. Numerous studies have demonstrated the positive effect of calcium on decomposition of fresh plant residues and there are indications that the processes of organic matter transformation are impeded by the presence of iron and aluminum.

科诺诺娃认为，土壤腐殖质含量与植物生物量总储量之间没有直接关系。 植物覆盖只是控制土壤形成和腐殖质积累的因素之一。 在各项研究中，已经研究了母质对土壤形成的影响，腐殖质形成的类型和含量也被调查。 将母岩中的钙加入到生物循环过程

中，促进了腐殖质的积累和上部生物土壤层中腐殖酸的优先形成。 在栽培土壤中，石灰在有机质转化上起着重要作用。 许多研究已经证明钙对新鲜植物残渣的分解有积极作用，并且有迹象表明有机物转化的过程因铁和铝的存在而受到阻碍。

In summation, Kononova stated that the outstanding role in humus formation is played by biochemical conditions and in many cases the importance of chemical and physiochemical properties of soil and parent rock outweighed that of bioclimatic conditions. In soils developed from parent material rich in bases resulted in the transformation of organic matter into more mature forms of humus. Changes to the organic fraction of soils have occurred through cultivation and the application of mineral and organic fertilizers. However in spite of cultivation and reclamation the humus still preserves features that are inherent to that of the particular soil type. This is to say that soils are self-organizing and decomposition of added organic matter will result in the formation of humic substances particular to that region and soil type where parent material plays a pivotal role.

总之，科诺诺娃指出生化条件在腐殖质形成中起到突出作用，且在许多情况下，土壤和母岩的化学和理化性质的重要性超过了生物气候条件。从富含碱的母质开发土壤使有机物转化为更成熟的腐殖质形式。通过栽培及施用矿物肥料和有机肥料，土壤有机部分发生了变化。 然而，尽管经过了耕种和开垦，腐殖质仍然保留了特定土壤类型固有的特征。 这就是说土壤是自组织，且添加的有机物质分解会导致形成特定于该区域和土壤类型的腐殖物质，其母质起到关键作用。

There is a direct correlation to soils formed from calcareous parent material and the quality of crops grown. This phenomena has been well documented by the French Wine Industry where Dr Gérard Sequin, University of Bordeux, stated, “active calcium carbonate is the one chemical constituent generally associated with wine quality”.

钙质母质形成的土壤与作物生长的质量有直接关系。 法国葡萄酒行业已经充分证明了这一现象，波尔多大学（University of Bordeux）的Gérard Sequin博士表示，“活性碳酸钙是与葡萄酒质量相关的一种化学成分”。

Recently Amy Trubek, Associate Professor in the Nutrition and Food Science department at the University of Vermont and Faculty Director for UVM’s graduate program in Food Systems concluded that, “the tests concluded that syrup produced from trees on limestone bedrock had the highest quantities of copper, magnesium, calcium and silica, which scientists hypothesized, had a role in the taste.”

最近，佛蒙特大学（ the University of Vermont，UVM）营养与食品科学系副教授和食物系统研究生课程主任Amy Trubek得出结论：“测试得出的结论是，石灰石基岩上生长的树木产生的糖浆其铜、镁、钙和二氧化硅含量最高，科学家推测，它们对食品的味道起作用。“

Possibly the most important attribute of calcium within the soil system is communication. The concept that soil is a habitat for functioning communities of organisms requiring the capability of communication is paramount to documented symbiotic relationships between soil biota and plants. As stated by Lynn Margulis, (1997), “Ca plays a critical role in the metabolism of all nucleated cells.” “Neuron-firing communication networks of the brain depend on calcium as telephone communication does on copper telephone wire.” Agriculture is an acidifying process resulting in Aluminum toxicity blocking Ca^{+2} transporters necessary for signaling resulting in soil biota and plants inability to sense its environment.

可能土壤系统中钙的最重要属性是通讯。 土壤是需要通讯能力的功能性生物群落栖息地这一概念，对于记录土壤生物群落与植物之间的共生关系至关重要。 正如Lynn Margulis（1997）所述，“钙在所有有核细胞的代谢中起着关键作用。”“正如电话通信需要在铜质电话线上的运行，大脑的神经元激发通信网络要依赖于钙。”农业是一种酸化过程导致铝毒性阻断Ca^{+2}转运蛋白所必需的信号传导，使土壤生物群和植物无法感知其环境。

Lastly soils that are developed from calcareous parent material result in the neo-formation of micaceous clays. In George Millot’s ‘The Geology of Clays’ he states that, “calcium ions play a prominent role in the synthesis of mica type clays, in which calcium does not intervene in the crystal lattice.” In this example calcium is a catalyst.

最后由钙质母质发育而成的土壤导致了云母粘土的新形成(neo-formation)。 在George Millot的“粘土地质学”中他指出，“钙离子在云母类粘土的合成中发挥着重要作用，其中钙并不干涉晶格。”在这个例子中，钙属于一种催化剂。

Calcium, more often than not, is cited as a critical contributor to soil restoration measures. It was the inherent reactivity characteristics and igneous calcite content of the SRC Complex that led to developing the resource starting in 1994.

钙通常被认为是土壤修复措施的关键因素。 是SRC复合体的固有反应特征和火成方解石含量促成了1994年以来的资源开发。

Apatite Series ($Ca5(PO_4)_3(F,Cl,OH)$) 磷灰石系列 ($Ca5(PO4)3(F,Cl,OH)$)

The phosphate ion is extremely reactive combining with at least 30 elements and under every conceivable geological setting resulting in approximately 300 phosphate minerals. Minute changes in impurities, pH, and crystal defects, to list of few, result in significant changes in solubility-reactivity behavior. For this reason wide discrepancies exist for solubility rates for many phosphate minerals and sources, (Nriagu, Moore, 1984). Different phosphate phase’s maybe stabilized or destabilized by the presence of various cations and anions, which do not have to be incorporated into the crystal lattice. Microorganisms play a very important role in the distribution of phosphorous on the earth’s surface, (Nriagu, Moore, 1984).

Microorganisms are closely involved in the cycling of phosphorous and current biogeochemistry and geomicrobiology research is providing greater insight into influences on phosphorous dissolution and mineralization within the soil system. Apatite mineral weathering by microorganisms is primarily accomplished by their acid production. Banfield, (1999), was able to detect pH values of 3 to 4 in proximity of cells attached to mineral grains within a local microenvironment. The bulk soil solution was pH 7. A lowering of pH between 3-4 will result in 10 to 1000-time increase in the mineral dissolution rate, (Banfield 1999). Phosphorous movement through the microbial biomass was faster with more phosphorous being bound (Mader, 2002). Research conducted by Peter vanStraaten, (unpublished data), demonstrated A. Niger inoculated cassava waste resulted in greater than 30% dissolution igneous fluorapatite. In many of the company's regional soil audits total phosphorous reserves were more than sufficient to meet the need of crop production. Deficiencies in growing crops could be overcome in these soil environments with more attention placed on improving microbial habitat. There is evidence that agriculture practices that focus on soil health through improved organic matter levels and soil structure will result in the existing soil phosphorous mineral reserves meeting crop requirements. Current research strongly suggest that adequate organic matter, soil aggregation and functioning communities of soil microorganisms play a critical role in the efficiency of phosphate nutrient cycle and maintaining biological available soil pools.

磷酸根离子与至少30种元素结合极其活泼，在每一种可能的地质背景下都能产生约300种磷酸盐矿物。 杂质、pH值和晶体缺陷的微小变化，都能导致溶解度－反应性行为发生显着变化。 由于这个原因，许多磷酸盐矿物和来源的溶解度差异很大（Nriagu，Moore，1984）。 不同的磷酸盐阶段可能由于各种阳离子和阴离子的存在而稳定或不稳定，这些阳离子和阴离子不必被结合到晶格中。 微生物在地球表面的磷分布中起着非常重要的作用（Nriagu，Moore，1984）。微生物与磷的循环和当前的生物地球化学密切相关，而且地球微生物研究正提供了对土壤系统内磷溶解和矿化影响的更加深入的了解。微生物造成的磷灰石矿物风化主要通过它们产酸而完成。班菲尔德（Banfield，1999年）能够在邻近细胞附着在局部微环境中的矿物颗粒附近检测到3至4的pH值。大块土壤溶液的pH值为7。降低pH值到3-4之间会导致矿物溶解速率提高10至1000倍（Banfield，1999）。随着更多的磷被束缚，通过微生物生物量的磷运动速度更快（Mader，2002）。 Peter van Straaten所做的研究（未发表数据）显示，尼日尔接种木薯废料导致超过30％溶解火成氟磷灰石。在该公司的许多地区土壤审核中，磷的储量总量足以满足作物生产的需求。在这些土壤环境中更多的关注改善微生物栖息地，种植作物中的缺陷便可以被克服。有证据表明，通过改善有机质含量和土壤结构，重视土壤健康的农业实践可使现有的土壤磷矿物储量满足作物需求。目前的研究强烈表明，适当的有机物质、土壤聚集和土壤微生物的功能群落在磷酸盐养分循环的效率和维持生物有效土壤池中起着关键作用。

Phosphate minerals are a favored host for radioactive ions and heavy metals, particularly cadmium. The phosphate fertilizer refining process removes radioactive ions but cadmium is incorporated into the finished fertilizer. Recent research is showing plant and animal cadmium uptake exceeding tolerable level intake guidelines established by the World Health Organization. Cadmium containing phosphate fertilizers were confirmed to have increased the Cd status both in soil and plants. In response New Zealand, Australia, Austria, Sweden and Finland have established guidelines and worked with the fertilizer industry to reduce Cd soil contamination. Austria, Sweden and Finland have enacted legislation to ban high cadmium fertilizers. As a result of this issue emphasis on phosphate production from carbonatite complexes has gained attention primarily because they do not have contaminant levels associated with sedimentary phosphorite deposits.

磷酸盐矿物质是放射性离子和重金属特别是镉的主要寄主。 磷肥在精炼过程中去除了放射性离子，但是镉却被掺入成品肥料中。 最近的研究显示，世界卫生组织制定的植物和动物镉吸收已超过可接受的摄入量指标。 已证实含镉磷酸盐肥料增加了土壤和植物中的镉含量。 新西兰、澳大利亚、奥地利、瑞典和芬兰做出响应制定了准则，并与化肥工业合作减少镉土壤污染。 奥地利、瑞典和芬兰已颁布立法禁止使用高镉化肥。因为这个问题，从碳酸盐复合物生产磷酸盐受到重点关注，主要是因其不具有与沉积磷矿石相关的污染物水平。

The New Zealand and Australian experience suggests that utilizing waste management guidelines could be ineffective in reducing Cd soil and plant levels. The plant availability of heavy metals is very dependent on soil conditions, farming practices and climate. Generally, metal uptake is high in acid soils; guidelines in New Zealand and Australia recommend maintaining soil fertility, particularly where cadmium levels have exceeded tolerable levels, through the application of organic matter and lime. Weathering of carbonatite deposits is economically important, because phosphate mineral content are markedly upgraded through weathering. There are two main weathering sequences, which result in apatite concentration.

根据新西兰和澳大利亚的经验表明，利用废物管理准则可能无法有效减少镉的土壤和植物水平。 重金属植物的可利用性非常依赖于土壤条件、耕作方式和气候。 一般来说，酸性土壤中的金属摄取量高; 新西兰和澳大利亚的指南中建议通过施用有机物和石灰来保持土壤肥力，特别是在镉含量超过可耐受水平的情况下。 碳酸盐矿床的风化有重要的经济效益，因为通过风化磷矿物的含量显着提高。 有两个主要的风化过程会影响磷灰石浓度。

1. Phosphate is remobilized by weathering then re-precipitated into a secondary phosphate deposit. 通过风化将磷酸盐再活化，然后再沉淀为二次磷酸盐沉积物。

2. The more soluble components, particularly carbonates, are weathered leaving residual concentration of phosphate. 更易溶解的成分——尤其是碳酸盐，被风化后剩下残

余浓度的磷酸盐。

The phosphate content of residuum quarried at the Spanish River Complex is currently 3.14% and the phosphate content in underlying bedrock is averaging 5%. This is contrary to the typical accumulation of phosphate minerals in residual sands overlying a carbonatite complex. Though continued exploration may lead to the discovery of residual apatite beds further geological and mineralogical interpretation is required to describe current phenomenon.

目前在西班牙河复合物开采残渣中磷酸盐含量为3.14％，而在底层基岩中磷酸盐含量平均为5％。这与覆盖在碳酸盐岩复合体上的残留砂岩中磷酸盐矿物的典型积累相反。虽然继续勘探可能会发掘出残余的磷灰石层，但还需要进一步的地质和矿物学解释来描述目前的现象。

The mineralogical characteristics of the SRC Complex studied by a number of geoscientists and the observations may help to explain current deposit unique mineral characteristics are:

由一些地球科学家和观测研究的SRC复合体的矿物学特征可能有助于解释目前矿床独特的矿物特征：

1. The intrusion has very low fluorine content suggested by the absence of the mineral pyrochlore $(Ca,Na)_2(Nb,Ta)_2O_6F$ (Hogarth, 1989). 由于缺乏矿物烧绿石 $(Ca,Na)_2(Nb,Ta)_2O_6F$，所以侵入的氟含量非常低（Hogarth，1989）。

2. Uranium, thorium, cadmium, arsenic and other heavy metal contents are low (Sage 1897a) particularly compared with other Carbonatite complexes (Hogarth 1989, Sage 1987b). 铀、钍、镉、砷和其他重金属含量较低（Sage 1897a），尤其是与其它碳酸盐复合物相比（Hogarth 1989，Sage 1987b）。

These observations are important, particularly low fluorine content, which precludes the formation of pyrochlore and the corresponding accumulation of radioactive ions and heavy metals, (Hogarth 1989). Low fluorine also results in the substitution of chlorine for fluorine in the apatite mineral. Chlorapatite is considered more soluble then fluorapatite, (Veldhuyzen, 2002). The complex is almost entirely comprised of sovite, (igneous calcite). This would result in a higher proportion of volatile elements (OH, CO2). With the lack of fluorine OH and carbonate substitution is also likely. These geological conditions would result in the formation of CO_2, chlorine and hydroxide substitution in the apatite mineral lattice.

这些观察结果很重要，尤其是低氟含量，这避免了焦绿石的形成和相应的放射性离子和重金属的积累（Hogarth 1989）。 低氟也导致磷灰石矿物中氟被氯而取代。 氯氟磷灰石被认为比氟磷灰石更易溶（Veldhuyzen，2002）。 该复合体几乎全部由黑云碳酸岩（火成方解石）组成。 这将造成挥发性元素（OH，CO2）比例更高。 缺乏氟和碳酸盐替代品也是可能的。 这些地质条件会导致在磷灰石矿物晶格中形成二氧化碳、氯和氢氧根替代物。

As well as influencing the size and shape of the apatite crystal carbonate substitution weakens the crystal structure therefore resulting in increased solubility. “High carbonate substitution is advantage in francolites; it allows the use of such a phosphorite by direct application or, in other words, the use of this phosphorite as a fertilizer without chemical pre-treatment," ‘(Nriagu & Morre 1984). This is very significant, preliminary analysis of SRC clay fraction indicates highest phosphorous content suggesting the existence of finely crystalline apatite group minerals.

除了影响磷灰石晶体的尺寸和形状，碳酸盐替代物也会削弱晶体结构，因此导致溶解度增加。“法兰基岩中的高碳酸盐替代物占有优势；可以允许直接施用这种磷矿石，换句话说，使用这种磷矿石作为肥料，不需要做化学预处理（Nriagu＆Morre，1984）。”这是SRC粘土非常重要的初步分析，显示磷含量最高，表明存在细晶磷灰石族矿物。

Unrefined rock phosphate applications to agricultural soils are increasing in response to the growth in organic food production. This demand will increase beyond the organic sector as ornamental chemical fertilizer use is restricted, environmental legislation restricts soluble phosphate applications and continued research is able to demonstrate the efficiency of microbial mediated plant available phosphorous. The initial studies of the apatite mineralogy also highlight the uniqueness of the SRC complex over others currently being studied.

随着有机食品生产的增长，未精炼的岩石磷酸盐对农业土壤的应用正在增加。这种需求将超出有机部分正如观赏性化肥的使用受到限制，环境立法限制了可溶性磷酸盐的应用，并且持续的研究能够证明微生物介导的植物有效磷的有效性。 磷灰石矿物学的初步研究也突出了SRC复合体与目前正在研究的其他复合体的独特性。

Boreal is currently developing research initiatives and actively seeking a PhD thesis candidate with the Earth Science Department, University of Western Ontario. The PhD thesis would coincide with anticipated advanced exploration of the complex. This thesis will not only document the complexes genesis, structure and mineral zonation but investigate apatite mineralogy and dissolution characteristics under microbial influences.

博莱公司目前正在开发研究计划，积极寻求西安大略大学（University of Western Ontario）地球科学系的博士论文候选人。 博士论文将与该复合体的预期深入探索相吻

合。 本论文不仅记录了复合体的成因、结构和矿物分带，还研究了微生物影响下的磷灰石矿物学特征和溶蚀特征。

Ijolite Rocks - Pyroxene Series ((Ca,Na)(Mg,Fe^{++},Fe^{+++})[Si_2O_6]) 霓霞岩 - 辉石系列 ((Ca,Na)(Mg,Fe^{++},Fe^{+++})[Si_2O_6])

The ijolitic rocks alternate with bands of biotite sovite. These ultramafic zones weather rapidly and constitute the most reactive phase of the complex. These mineral series are amongst the most cited in CO2 sequestration through silicate mineral weathering.

霓霞岩与黑云母带相交替。 这些超镁铁质区域迅速蔓延并构成复合体最活跃的阶段。 这些矿物系列是通过硅酸盐矿物风化的二氧化碳封存中引用最多的。

Geoscience queries discussed with Wilfred Laurier and Algoma Universities that are of interest and pertinent to the effectiveness of SRC is the effect of the silicate mineral weathering on soil carbon and nitrogen pools.

加拿大劳瑞尔大学（Wilfrid Laurier）和阿尔哥玛大学（Algoma）讨论的与SRC有效性相关的地球科学问题是硅酸盐矿物风化对土壤碳和氮库的影响。

Primary Biotite Series and Secondary Vermiculite Clay Minerals 原生黑云母系列和次生蛭石粘土矿物。

The clay minerals are layer-type aluminosilicates, ever-present on our planet in rocks, soils and oceans. The role of clay in soil is fundamental; it is their permanent structure and colloidal size, with their unique surface properties that play a major role in the biochemical cycling of plant nutrients.

粘土矿物是层状硅铝酸盐，在我们的星球上永远存在于岩石、土壤和海洋中。 粘土在土壤中的作用是基础根本; 它们的永久性结构和胶体大小、独特的表面性质在植物营养物的生物化学循环中起主要作用。

“The transformation of biotite to vermiculite with the release of the interlayer K is perhaps the most important biologically mediated geochemical reactions occurring in the rhizosphere” (Banfield, Proc. Natl. Acad. Sci. USA 96, (1999)). As the potassium is released the exchange capacity is increased and is characteristic of the clay mineral illite. With complete removal of K interlayer planes vermiculite and montmorillonite clay minerals are produced, (Hinsinger, P., Elsass, F. Jaillard, B. & Robert, M. (1993)). The transformation of biotite to vermiculite within the soil system is rapid. Experiments conducted by Mortland (1956), Spyridakis et al. (1667) and Weed et al. (1969) documented biotite functioned as well as soluble salt (KCl) as a source of K.

“黑云母到蛭石的转化伴随层间钾的释放可能是发生在根际的最重要的生物介导地球化学反应。”（班菲尔德，美国国家科学院，1999） 随着钾的释放交换能力增加，这也是粘土矿物伊利石的特征。随着钾层蛭石和蒙脱石层完全去除，粘土矿物产生了（Hinsinger，P.，Elsass，F.Jaillard，B.＆Robert，M。（1993））。 土壤系统内黑云母向蛭石的转化很快。 Mortland（1956）Spyridakis等人（1667）和Weed等人（1969）记录了黑云母的功能以及可溶性盐（氯化钾KCl）作为钾的来源。

Anne Bakken, (1997), conducted pot trial experiments growing with different K sources. Bakken concluded that during the first period of plant growth plants treated with KCl absorbed more than 70% of the potassium added. During the second growth period biotite carbonatite supplied as much K as KCl fertilizer. K-feldspar did not supply significant amounts of K to barley plants. Bakken (2000) transitioned from pot trials to grassland field applications covering a wide diversity of soil types. The results from this three trial are highlighted in her publishing in Nutrient Cycling in Agroecosystems:

Anne Bakken（1997）进行了用不同钾来源生长的盆栽试验实验。 Bakken总结说，在植物生长的第一个阶段，用氯化钾处理的植物吸收了超过70％的钾。 在第二次生长阶段，黑云母碳酸盐提供的钾含量与氯化钾肥料相当。 钾长石不会向大麦植物提供大量的钾。 Bakken（2000）从盆栽试验过渡到覆盖各种土壤类型的草场应用。 这三项试验的结果在她出版的《农业生态系统养分循环》中得以强调：

“Crushed rocks and mine tailings containing biotite, K-feldspar and nepheline as K-bearing minerals were applied as K fertilizers in a series of 15 grassland field trials. A treatment with KCl as K-source out yielded treatments with rock based fertilizers in the first and the second experimental year. In the third and last year of the study when no K fertilizers were supplied, previously added carbonatite and biotite concentrate supported grass growth as much as previously added KCl did. Although it is concluded that a substantial part of the K bound in biotite and/or nepheline in crushed carbonatites, biotite concentrate and epidote schists is plant available, these rock/mineral products weathered too slowly to replenish the native pool of plant available K within a three year period with five harvests. The K bound in K-feldspar seemed to be nearly unavailable for the grass plants.”

“含有黑云母、钾长石和霞石的含钾矿物碎石和尾矿，被当作钾肥施用在一组15个草地田间试验中。 在第一个和第二个实验年里，在岩石基肥料中用氯化钾作为钾源进行处理。 在研究的第三年和最后一年，当没有施用钾肥时，之前添加的碳酸盐和黑云母精矿支撑草的生长，正如之前添加的氯化钾一样。 虽然可以得出结论，大部分钾在黑云母和/或霞石中与压碎的碳酸岩、黑云母精矿和绿帘石片岩结合是可被植物利用的，但这些岩石/矿物产品风化得太慢而无法补充三年五期收成。 钾长石中的钾几乎无法用于草场植物。”

Vermiculites are classified as high activity clays. This means that this group of clays have a wide range of mineralogy resulting in a wide range of compositions where the interlayer spaces are charged and hydrated to various extents resulting in a wide diversity in behavior, Pedro (1997). Clays being tiny nanocrystalline particles are essential components of the earth's surface. "Any clay, even a monomineral clay is a population of different particles. Each particle is itself a population of micro- domains. When the environment changes, each micro-domain and each particle starts changing. Each of them shift towards a new thermodynamic equilibrium according to its own speed: population dynamics are going on. Population dynamics apply to clay mineralogy today" Millot (1989).

蛭石被归类为高活性粘土。这意味着这组粘土具有广泛的矿物学意义，形成了各种各样的组合物：其中层间空间被充电与水合到不同程度，导致了行为的广泛多样性（佩德罗1997）。 粘土是微小的纳米晶颗粒，是地球表面的重要组成部分。"任何粘土，甚至单矿物粘土都是由不同颗粒组成的群体。每个粒子本身即是一个群体的微畴。当环境发生变化时，每个微畴和每个粒子开始变化。每个微畴和粒子按照自己的速度转向一个新的热力平衡：群体动态正在进行中。现如今群体动力学适用于粘土矿物学。"（米勒，1989）

The Spanish River Carbonatite Complex is an exceptional source of both biotite and vermiculite. Though not widely recognized in agriculture today, ongoing research will result in highlighting the very real problem of clay destruction through progressive acidification and clay re-mineralization could play a key role in soil nutrient cycling and rejuvenation. Secondly K bearing biotite, as well as, supplying comparable quantities of K to growing plants as KCl enhanced soil system dynamics with the formation of vermiculite.

西班牙河碳酸盐岩复合体是黑云母和蛭石的特殊来源。 尽管目前在农业中尚未得到广泛认可，但正在进行的研究将突出强调通过逐步酸化过程造成粘土破坏的真正问题，且粘土再矿化可能在土壤养分循环和复兴中发挥关键作用。 其次，钾承载了黑云母，且蛭石形成时氯化钾增强了土壤系统动力学，为植物生长提供相当数量的钾。

Rare Earth Elements 稀土元素

On a visit to the Spanish River Carbonatite Complex, Dr. Ron Sage, (personal communication 1999) was asked his opinion of why the melting temperatures for carbonatites was so low and was there a correlation between this phenomena and why the Spanish River Complex was rapidly oxidizing . Sage believes the melting temperature of the calcite in carbonatites may have been impacted by catalytic trace elements and this could transcend into the unique reactivity properties exhibited.

在一次探索西班牙河碳酸盐岩复合体时，Ron Sage博士（私人交流，1999年）被问及他对碳酸岩熔化温度为何如此之低的观点，以及这种现象是否与西班牙河碳酸盐岩复合体迅速氧化的原因有所关联。 Sage认为，碳酸岩中方解石的熔化温度可能受到催化痕量元素的影响，这可能会超出已表现的独特反应性。

The SRC Complex was targeted for acquisition and exploration for agronomic potential because of high carbonate content but also because of its very low metal levels. As stated a common signature of all ultramafic rocks are anomalous levels of lanthanides. The potential for detritus effects to animals, plants, soil, soil biota and aquatic environments was thus warranted.

由于碳酸盐含量高，而且其金属含量很低，SRC复合体的目标是获取和探索农艺潜力。 如上所述，所有超基性岩石的共同特征是异常水平的镧系元素。 因此动物、植物、土壤、土壤生物群和水生环境必然会发生碎屑效应。

Currently China is the only country that has the commercial use of rare earths in agriculture. Limited studies were published by Russian and Bulgarian scientists in the early nineteenth century. Chinese research began in 1972 and early outstanding results with low level applications resulted in adoption. The physiological responses include increases in chlorophyll content resulting in darker green foliage, enhanced root development, greater production of roots, stronger thicker stems and better colored fruit in crops such as apples, oranges and watermelons. Yield responses included increases in crops such as wheat, increased sugar content in sugar cane, increased vitamin C content in grapes and apples, and increased fat and protein content in soybeans. These gains were made without any known impact on ecological sustainability or biodiversity.

目前中国是唯一有农业商用稀土的国家。 十九世纪初，俄罗斯和保加利亚的科学家发表了有限的研究报告。 中国的研究始于1972年，早期的采用源于优秀成果和低水平的应用。 生理学反应包括增加叶绿素含量导致绿叶颜色更深、增强的根系发育、更大的根生产、更厚的茎和更好的有色水果，如苹果、桔子和西瓜等作物。 产量反应包括小麦等作物的增加、甘蔗糖含量的增加、葡萄和苹果中维生素C含量的增加以及大豆脂肪和蛋白质含量的增加。 这些成果对生态可持续性或生物多样性没有任何已知的影响。

The obvious language barrier and the lack of experimentation details and statistical treatment of data warranted further investigation. Research conducted by Australia, Germany and Austria showed conflicting results and could not confirm the outstanding crop enhancements reported by the Chinese, (Kerstin Redling 2006). Several hypotheses have been proposed as to how rare earths affect plant growth ranging from effects on transportation mechanisms, accumulation of ions, nitrogen fixation over influences on calcium metabolism and photosynthesis to the protection against certain plant diseases or draught, (Kerstin Redling 2006).

显著的语言障碍以及缺乏实验细节和数据统计处理的问题值得进行进一步调查。 澳大利亚、德国和奥地利进行的研究显示了相互矛盾的结果，并且无法证实中国报道的杰出作物增强效果（Kerstin Redling，2006）。 已经提出了几个关于稀土如何影响植物

生长的假设，包括对运输机制的影响、离子的积累、固氮作用对钙代谢和光合作用的影响、以预防某些植物疾病或干旱（Kerstin Redling 2006）。

As well as utilizing lanthanides in crop production the Chinese also use REE's as a feed additive in livestock. Where confirmation of Chinese research has not been substantiated has been in livestock feeding experiments. Positive effects on animal growth and feed conversion in both pigs and poultry have been demonstrated, (Kerstin Redling 2006).

除了在作物生产中利用镧系元素外，中国人还使用稀土元素作为家畜饲料添加剂。 在中国研究尚未得到证实的情况下，已经进行了家畜饲养实验。 已证实对猪和家禽的动物生长和饲料转化有积极作用（Kerstin Redling，2006）。

Unpublished research was carried out by the principles of the SRC project on small laying chicken flocks starting 1995. Observations followed Germany, Switzerland and the Netherlands studies and as well as increased feed efficiency SRC substantially added to egg shell thickness. Today Boreal has commenced facilitating scientifically validated research opportunities here in Canada.

从1995年开始的未发表的研究，以SRC项目原则进行的小规模鸡群项目。观察结果依据德国、瑞士和荷兰的研究，以及提高的饲料效率，SRC大大增加了蛋壳厚度。 今天，博莱公司已经开始在加拿大推动经过科学验证的研究机会。

Geochemistry of the Spanish River Carbonatite Complex 西班牙河碳酸盐岩复合体的地球化学

Concepts of Soil Degradation 土壤退化的概念

Soil Acidification 土壤酸化

Agriculture is an acidifying process that is addressed through liming. Liming recommendations are primarily based on soil pH measurements. This does not take into account soil dynamics that have possibly a greater influence on soil and plant health such as organic matter loss and compaction.

农业是一个酸化过程，通过限制来解决。 石灰添加的建议主要是基于土壤pH值测量。这并不考虑对土壤和植物健康可能有较大影响的土壤动力学，如有机质损失和压实。

An important weathering feature in the calcareous soils of Southern Ontario is the dissolving of calcium carbonate concretions and nodules in glacial till parent material. This is because $CaCO_3$ maintains a preserving effect and the dissolution of calcium speeds up the weathering and soil development process. In areas of heavy to moderate rainfall, like Southern Ontario, the loss of calcium from leaching and erosion is considerable. A study conducted in Ithaca N.Y., reported in US Geological Survey Circular 1017 and The Nature and Properties of Soils by Nyle C. Brady, showed the following losses on a silty clay loam:

安大略南部的石灰性土壤的重要的风化特征就是碳酸钙结石溶解以及冰碛母质结节。这是由于碳酸钙起到保护作用，而钙的溶解加速了风化和土壤发育过程。像安大略南部这样的大到中等降雨量的地区，淋溶和侵蚀造成的钙流失相当严重。Nyle C. Brady在纽约伊萨卡进行的一项研究：《自然及土壤性质》，刊登在美国地质调查报告第1017期上，其中表明粉质粘土有如下损失：

- Bare Soil – 398 lbs/acre/year 裸土- 398磅/英亩/年

- Rotated Crop Land – 230 lbs/acre/year 轮作土地- 230磅/英亩/年

- Continuous grass – 260 lbs/acre/year 连续种植- 260磅/英亩/年

Losses to erosion, even on 4% slope, in Missouri, USA experiments showed the following:
在美国密苏里州的侵蚀损失，甚至有4%增长，实验显示如下：

- Continuously grown corn – 220 lbs/acre/year 连续种植玉米–220磅/英亩/年

- Rotation; corn, wheat, clover – 85 lbs/ acre/year 轮作；玉米、小麦、苜蓿–85磅/英亩/年

Using the best-case scenario where cover crops and proper rotation is practiced, average losses would amount to approximately 315 lbs/acre/year. According to Brady this would indicate a required application of 1.1 to 1.3 tons /acre of $CaCO_3$ in a 4 to 5 year rotation. He goes on to conclude that the test results verify the importance of lime in any scheme of fertility management in areas of medium to heavy rainfall. Yearly losses of calcium, due to leaching and weathering, exceed all other macronutrients.

在进行覆盖作物和适当的轮作试验土地中选出的最佳案例显示，平均损失将达到约315磅/英亩/年。根据Brady的说法，这将意味着在4到5年的轮作中必须使用1.1到1.3吨/英亩的碳酸钙。他接着得出结论说，试验结果证实了石灰在中到大降雨地区的施肥管理计划中的重要性。由于浸出和风化造成每年的钙亏损，超过了所有其他营养素。

Since the focus on acid rain, scientists have been concerned that acids could deplete essential nutrients. Research starting in the 1980's has attempted to understand the effects of acid rain, particularly regions that have little buffering capability, (i.e. soils formed from parent material containing little calcium). A report, Soil-Calcium Depletion Linked to Acid Rain and Forest Growth in the Eastern United States, USGS, published in February 1999 explains the mechanisms set in motion with acid deposition, resulting in forest losses on the Precambrian Shield and Eastern United States.

自从关注酸雨以来，科学家们一直担心酸会消耗必需的营养素。从80年代开始，人们就试图研究了解酸雨的影响，特别是那些没有缓冲能力的区域，即由钙含量低的母质形成的土壤。美国地质调查局于1999年2月发表了一份报告："美国东部的土壤钙耗竭与酸雨和森林生长有关"。此报告阐释了酸雨沉积的机制，致使前寒武纪地盾、加拿大东部以及美国的森林损失。

The breakdown of high-energy clay minerals also results in excessive leaching due to the loss of exchange sites in the B-horizon. The increased concentration of exchangeable aluminum is taken up by roots and eventually is recycled unto the forest floors. Dissolved aluminum can also be transported to the forest floor by a rising water table. Aluminum, having a greater affinity for negatively charged further displaces plant nutrients on soil exchange sites resulting in overwhelming the soil system.

高能量粘土矿物的分解也导致了在淀积层交换损失因而过度浸出。交换性铝浓度的增加由根部吸收，最终循环到森林表面。溶解的铝也可以通过上升的水位被输送到森林地面。铝对负电荷具有更大的亲和力，进一步取代了土壤交换位置上的植物营养物，从而导致土壤系统过载。

Acid rain unquestionably accelerates the mineral weathering process and in the absence of calcium causes the release of aluminum. Adequate calcium maintains the base cation exchange relationship. This acidity may also increase the solubility of B, Mn, Cu, Cd, As and Ni to toxic concentrations. Phosphorous is converted to insoluble Fe and Al compounds in aluminum saturated soil solutions. Potentially a more serious problem is the long-term application of acidifying fertilizers. Nitrogen and phosphorous fertilizer are acid generating and in any fertility recommendation an estimated 1.8 to 5.0 lbs of calcium carbonate ($CaCO_3$) is required to neutralize the acidity generated from one pound of ammonium nitrate (NH_4NO_3), Monoammonium Phosphate,($NH_4H_2PO_4$) and diammonium phosphate ((NH4)2HPO4).

酸雨无疑加速了矿物风化过程，而在缺乏钙的情况下，会导致铝的释放。充足的钙维持碱阳离子交换关系。这种酸性还可以增加硼、锰、铜、镉、砷和镍（B, Mn, Cu, Cd, As and Ni)对有毒浓度的溶解度。磷在铝饱和土壤溶液中转化为不溶性铁和铝化合物。长期施用酸化肥料可能会是一个更严重的问题。氮和磷肥料产生酸，在任何肥力建议

中，估计需要1.8 - 5.0磅碳酸钙(CaCO3)来中和由1磅硝酸铵(NH4NO3)、磷酸一铵(NH4H2PO4)和磷酸二铵((NH4)2HPO4)产生的酸。

Aluminum toxicity is ubiquitous, meaning it affects animals, plants and microbes. In animals excessive aluminum results in neuronal damage. Animals, which include humans, get aluminum through drinking water, aluminum pots and food. In plants aluminum toxicity results in poor plant health, poor yields and poor nutrient content. Plants obtain aluminum through dissolved aluminum in the soil solution. Aluminum has a pronounced effect on mycorrhizal fungi resulting in poor nitrogen fixation.

铝的毒性无处不在，这意味着它会影响动物、植物和微生物。 在动物中过量的铝导致神经元损伤。 包括人类在内的动物通过饮用水、铝罐和食物获得铝。 在植物中铝的毒性导致植物健康状况不佳、产量差以及营养成分低下。 植物通过土壤溶液中溶解的铝获得铝。 铝对菌根真菌有明显的影响，导致固氮效果差。

Table : 3 Acidity generated from common N sources

表格：3 普通氮源产生的酸度

Soil Acidity and Liming, Clemson University

土壤酸度与浸石灰，克莱姆森大学

Nitrogen and Phosphate Source氮磷来源	**lb CaCO3/lb Fertilizer needed to neutralize the acidity**每磅中和酸度所需的肥料中碳酸钙量
Anhydrous ammonia 无水氨	1.8
Urea 尿素	1.8
Ammonium nitrate 硝酸铵	1.8
Ammonium sulfate 硫酸铵	5.4
Monoammonium phosphate 磷酸一铵	5.4
Diammonium phosphate 磷酸二铵	3.6

Aluminum toxicity is a widespread problem and is one of the major limitations to world food production as well as reducing the nutrient content of foods. This is especially true in areas where food production is critical and population growth is the highest. Al toxicity is progressive, without remediation it will not go away. 300 ppm aluminum in plant tissue analysis is regarded as toxic and is common in soils with a pH of 5.5 or lower. Soils at higher pH and generally regarded as having sufficient buffering capacity to resist aluminum uptake by plants have shown symptoms of Al toxicity. This is due to physical and chemical soil impaction, which has resulted in creating soil hardpans and a significant reduction in soil nutrient cycling capability.

铝中毒是一个普遍存在的问题，是限制世界粮食生产和降低粮食营养含量的主要因素之一。在粮食生产至关重要和人口增长最快的地区尤其如此。铝的毒性是渐进的，如果不进行补救，它就不会消失。300百万分比浓度的铝在植物组织分析中被认定有毒，且在pH为5.5或更低的土壤中常见。pH值较高且通常被认为具有足够缓冲能力以抵抗植物吸收铝的土壤也已经显示出铝中毒的症状。这是由于物理和化学土壤冲击，造成土壤硬化和土壤养分循环能力的显著降低。

Silica Cycle 二氧化硅循环

Terrestrial silica mobility is becoming an important area of research because of the effects agriculture has on global biochemical Si cycles, (Vandevenne 2012).

由于农业对全球生物化学硅循环的影响，陆地硅的流动性正在成为一个重要的研究领域（Vandevenne，2012）。

Organic Matter and Nitrogen 有机物和氮

The mechanisms and pathways of soil nitrogen fixation are well documented. The management of the soil nitrogen cycle is clearly the most important issue facing agriculture today. More effort and capital is being spent on the management of nitrogen than any other plant nutrient, (Brady 1999). The major reasons for this are its essential role in food production and its impact on the environment. Too little results in crop failures, starvation and farm ruin, too much endangers the health of all living things, (Brady 1999). The management of nitrogen with escalating energy costs coupled with increased environmental awareness is resulting in a tremendous amount of resources devoted to developing solutions to ensure both farm productivity and the environment can be maintained simultaneously. These efforts have brought the critical role of soil organic matter and the biological mechanisms that incorporate carbon and nitrogen into a functioning soils system into play.

土壤固氮的机制和途径已有详细记载。 土壤氮循环的管理显然是当今农业面临的最重要的问题。 更多的努力和资金正在用于氮的管理上，而不是其他任何植物营养素，（Brady，1999）。 其主要原因是它在食品生产及其对环境的影响方面的重要作用。极少造成作物歉收、饥饿和农场毁灭，更多的是危及所有生物的健康（Brady，1999）。 随着能源成本的不断提高以及环境意识的提高，氮的管理将导致大量资源用于开发解决方案，以确保农场生产力和环境同时得到保持。 这些努力带来了土壤有机物质的关键作用以及将碳和氮纳入土壤系统运作的生物机制。

Nitrogen alters plant composition more than any other mineral nutrient. Excess nitrogen fertilization will result in nitrogen content at the expense of most of the other major plant constituents, (Marschner 2002). Ironically it is adequate nitrogen that results in enhanced protein synthesis represented by lipids, chlorophyll, carotene, vitamins A and B, (Marschner 2002).

氮比其他矿物营养素更能改变植物组成。 过量的氮肥将导致氮含量以牺牲大部分其他主要植物成分为代价（Marschner，2002）。 具有讽刺意味的是，正是足够的氮导致以脂质、叶绿素、胡萝卜素、维生素A和B为代表的蛋白质合成增加（Marschner，2002）。

From a soil microbiological prospective data is available that indicates increased populations of bacteria and fungi but this has been tempered by the fact that direct positive responses to mineral nitrogen will only occur if the soil system has adequate carbon at the time of fertilization, (Domsch 1985). The cultivation of soils results in a rapid loss of organic matter, (Juma 2002). Potentially as critical as loss of microbial habitat due to organic matter depletion are changes to soil microbial communities. Excess N in carbon-limited soils has negative effects on microbial biomass (Beck, 1984). An experiment, conducted by Smyk, Rozycki and Barabasz, (1985) found applications of mineral nitrogen (120 to 360 kg/N/Ha/year) resulted in distinct changes in the structure of microbial communities in the soil. After three years of test work, on mountain meadow grasses, at the above-mentioned rates the following observations were made:

从土壤中可以得到微生物学的前景数据，表明细菌和真菌的数量增加，但这种情况受到了以下事实的影响：对矿质氮的直接积极响应只有当施肥时土壤系统具有足够的碳时才会发生（Domsch，1985）。 土壤的培养会导致有机物的快速损失（Juma 2002）。 可能与微生物栖息地因有机质枯竭而丧失同样重要的是土壤微生物群落的变化。 碳限制土壤中的过量氮对微生物生物量具有负面影响（Beck，1984）。 由Smyk、Rozycki和Barabasz（1985）进行的一项实验发现，施用矿物氮（120至360 kg / N / Ha /年）导致土壤中微生物群落结构发生明显变化。 经过三年的试验工作后，在山地草地上按上述速率提出以下观察结果：

i) Nitrosamines were prevalent in the fertilized plot, none were found in the control plot. Nitrosamines may bring about mutagenic phytoxic (poisonous to plants), carcinogenic and teratogenic (developmental malformations) in microorganisms, plants and animals. 亚硝胺普遍存在于施肥田中，在对照田中未发现亚硝胺。 亚硝胺可能导致微生物、植物和动物的致突变性（对植物有毒）、致癌和致畸（发育畸形）。

ii) Decreases in the number of bacteria accompanied by increases in the population of fungi of the genera Fusarium, Penicillium and Verticillium. These changes have a negative effect on the stability of the ecosystem. 随着镰刀菌属、青霉属和轮枝菌属真菌种群数量的增加， 细菌数量减少。 这些变化对生态系统的稳定性有负面影响。

iii) A 77% reduction in the number of plant species composing the meadow sward. 组成草场植物的物种数量减少77 %。

There is sufficient evidence that nitrogen fertilizer stimulates microbial growth though enhanced use of soil organic carbon, (Westerman and Tucker 1974). Loss of organic matter through tillage and fertilizer application will result in organic matter levels at levels not adequate for the requirements of resting soil microbial populations, (Anderson and Domsch 1985). This work suggests that depleted organic matter content in cultivated soils coupled with heavy nitrogen fertilizer applications has created an environment that is detrimental to all facets of the biosphere. Instead of creating an environment which will increase soil microbe diversity which intern ensure soil pools of essential plant nutrients current practices have led to requiring higher quantities of inputs. The reduction of plant species as a result of changing soil microbial communities suggests that the symbiotic relationship between plants and microbes is critical and is lost due to longterm application of N fertilizer. This may not only demonstrate the need for soil carbon renewal, but the type of carbon additions. Microbes may have very specific nutrient requirements and to encourage microbial diversity may require diversity of mineral constituent's within organic matter base.

有足够的证据表明氮肥通过增加土壤有机碳的使用来刺激微生物生长（Westerman和Tucker，1974）。耕作和施肥造成的有机质流失将导致有机质水平达不到土壤微生物种群静息的要求（Anderson和Domsch，1985）。这项工作表明耕作土壤中的有机质含量减少，加上大量氮肥的施用，造成了一种对生物圈各个方面都有害的环境。这种方式确保当前实践必需的植物养分的土壤库需要更多的投入，而非创造一个会增加土壤微生物多样性的环境。土壤微生物群落变化导致的植物种类减少，这表明植物与微生物之间的共生关系至关重要，且由于长期施用氮肥而丧失。这可能不仅显示了土壤碳更新的必要性，而且还表明了碳添加的类型。微生物可能具有非常特定的营养需求，为了促进微生物多样性，需要在有机物基础内具有矿物质成分的多样性。

Soil Compaction 土壤压实

Plant Nutrition 植物营养

Concepts of Sustainable Agriculture 可持续农业的概念

An Overview of Microbial Mineralogical Interactions within the Soil System 土壤系统中微生物矿物相互作用概述

In K.H. Domsch presentation at the proceedings of the Federation of European Microbiological Societies Symposium, (1985) on "Microbial Communities in Soil" the discussion on the contribution of modern agriculture practices to current environmental problems has come to the forefront due to the culmination of warnings presented in the media. According to Domsch the catalyst was the American biologists, Paul Ehrlich, who in 1972 claim that, "world agriculture today is an ecological disaster."[6]

由于来自媒体的警告热潮，K·H·多姆施（K.H. Domsch）在欧洲微生物学会联合讨论会（1985）关于"土壤中的微生物群落"的会议中介绍了关于现代农业实践对当前环境问题作出的贡献的讨论。 根据多姆施的说法，其催化剂是美国生物学家保罗·埃利希（Paul Ehrlich），他在1972年声称："现今的世界农业是一场生态灾难。"6

The disruption of geochemical patterns due to human activity has directly manifested into changing climate. Until recently very little attention has been placed on soil degradation as a contributing factor. Though the quantification of soil health is far from complete the importance of soil microbial communities in regulating global geochemical cycles is certain. Though agriculture has been cited as a major contributor to the problem a greater understanding of the dynamics of the pedophere gives rise to the real opportunity agroecosystems can play in mediating current global environmental problems.

由于人类活动造成了地球化学模式被破坏，直接表现为气候变化。 直至今日，人们极少关注土壤退化是其中一个促成因素这一问题。 虽然土壤健康的量化还远未完成，但调控全球地球化学循环的土壤微生物群落是极其重要的。 尽管农业被认为是造成这一问题的主要原因，但更深入地了解土壤动力学，可以为农业生态系统调解当前的全球环境问题提供真正的机会。

The role of living organisms in mitigating geological change is proportional to mass of the life form and the mass of microorganisms combined is much greater than that of any other life form on earth. It is the microbial world that plays the prominent role in the geological and geochemical processes the shape the planet. The natural division of life on Earth is not plants and animals rather bacteria, cells without a nucleus and all other life forms. Bacteria evolution have led to all life processes fermentation, oxygen breathing, removal of nitrogen gas from the air and photosynthesis (Margulis, Sagan 1997). Microorganisms create enormous stores of chemical energy from a multitude of complex geochemical reactions. These reactions are occurring at inconceivable speed (Vernadsky 1939). The catalytic effect of biological systems can accelerate geological processes often by a factor of more than a million (Westbroek, Bruyn 1996).

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[6] Paul R. Ehrlich, Anne H. Ehrlich, (1972), Population, Resources, Environment: Issues in Human Ecology, Second Edition. Paul R. Ehrlich，Anne H. Ehrlich，（1972年），人口、资源、环境：人类生态学问题，第二版。

生物体在缓解地质变化中起到的作用与其生命形态的质量成正比，而微生物的总量大于地球上其他任何生命形态的总量。 微生物世界在地质学和地球化学过程中起着突出作用。 地球上生命的自然分化不是植物与动物，而是细菌、没有细胞核的细胞以及所有其他生命形式。 细菌的进化导致了所有生命过程发酵、呼吸氧气、从空气中去除氮气和光合作用（Margulis，Sagan，1997）。 微生物从许多复杂的地球化学反应中创造出巨大的化学能量储备。 这些反应以不可思议的速度发生（Vernadsky，1939）。 生物系统的催化作用通常可以使地质过程加速超过一百万倍（Westbroek，Bruyn，1996）。

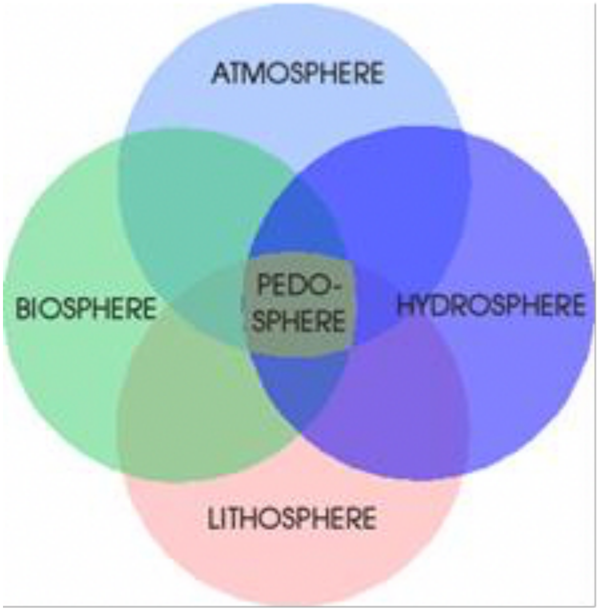
The ability of bacteria to transfer different bits of genetic material from one individual to another gives the entire world bacteria kingdom access to a single gene pool. The speed of this process over mutation by larger animals is far superior. Where it would take animals millions of years to adjust to changes on a world wide scale it would take bacteria two years. The ability to communicate and exchange material on a worldwide basis allows the microcosm to adapt to large external changes in the environment that ultimately affect all plants and animals, (Margulis, Sagan 1997).

细菌有能力将不同位点的遗传物质从一个个体转移到另一个个体使得整个世界的细菌王国能够获得单个基因库。 这个过程比大型动物的突变速度要快得多。动物需要数百万年才能适应全球范围的变化，细菌则需要两年的时间。在全球范围内交流和交换材料的能力使微观世界能够适应环境中那些最终影响到所有动植物的巨大外部变化（Margulis，Sagan 1997）。

Current research suggests microorganisms significantly affect mineral dissolution rates and thus the formation of soil. This implies that the earth's systems evolved simultaneously and long-term forecasting of climate change requires a comprehensive understanding of mineralogy, soil chemistry, and microbial dynamics. Microbial mediated mineral transformations occurring at the surface of our planet are essential to the biosphere. In fact it is biological mineralogical interactions occurring at the surface of our planet that results in the formation of soil, rocks, geochemistry of the seas and particulate content of the atmosphere, (Krumbein & Dyer 1985). Mineral change at the surface of the earth is called weathering. The term weathering has the negative connotation of mineral destruction. The geological change mitigated by the biosphere is not a destructive force but one of transformation.

目前的研究表明，微生物显著影响了矿物溶解速率，从而影响土壤的形成。 这意味着地球系统同时进化，气候变化的长期预测需要全面了解矿物学、土壤化学和微生物动力学。 在地球表面发生的微生物介导的矿物转化对生物圈至关重要。 实际上，在我们星球表面发生的生物矿物相互作用造成了土壤、岩石的形成，海洋地球化学和大气颗粒物含量（Krumbein＆Dyer 1985）。 地球表面的矿物变化称为风化。“ 风化”一词具有矿物破坏的负面含义。生物圈减缓的地质变化不是破坏性的，而是转化性的。

Living systems do not only adapt to the environment but shape it to maximize its geochemical potential (Krumbein & Dyer 1985). The development of the soil profile is a beautiful illustration of biological mediated mineral adaptation to maximize nutrient cycling. Where soil mineralogy ultimately dictates the geochemical potential of the landscape the soil system determines how effective this potential will be utilized by plants and soil microorganism.



生物系统不仅适应环境，还塑造环境，使地球化学潜力最大化(Krumbein & Dyer 1985)。土壤剖面的发展是生物介导矿物质适应最大化养分循环的最佳例证。土壤矿物学最终决定景观地球化学的潜力，而土壤系统决定了植物和土壤微生物利用这种潜力的效率。

Dynamics of the Pedosphere 动植物界的动态

(Juma and Nickel 2000)

The bulk of living organisms exists within a few meters of the Earth's surface where liquid, solid and gaseous phases mingle. The result of this intermingling is a distinct thin geological profile comprised of clay, carbonates and oxides known as the pedosphere. The development of soil requires two distinct geological processes; the formation of parent material and the second process is the actual formation of a soil profile. Whereas the parent material ultimately dictates the geochemical potential of the landscape the soil system determines how effective this potential will be utilized by plants and soil microorganisms.

大部分生物存在于地球表面几米之内，在那里，液相、固相和气相混合。这种混合的结果是由粘土、碳酸盐和氧化物组成的明显的薄地质剖面，称为土壤圈（pedosphere）。土壤发育需要两个截然不同的地质过程；母质的形成和土壤剖面的实际形成。尽管母质最终决定了景观的地球化学潜力，但土壤系统决定了植物和土壤微生物将如何有效利用这一潜力。

Soil formation is driven by biological processes. Microorganisms create enormous stores of chemical energy from a multitude of complex geochemical reactions occurring at inconceivable speed, (Vernadsky 1939). The catalytic effect of biological systems can accelerate geological processes often by a factor of more than a million, (Westbroek, Bruyn 1996). The consequence of this complex interaction is the accumulation of organic matter, humic substances incorporated into the soil and the formation of clays. This results in the formation of vertically stratified layers or horizons recognized as the soil profile. Generally there are three horizons within a soil profile, known as A, B, and C. The A and B-horizons represent the true developed soil where biological activity and clay formation takes place. The C- horizon is the parent material from which the soils are formed. The C horizon is only influenced by geochemical weathering and much of the original mineral structure remains recognizable. The biological activity within the A-horizon results in soluble compounds and clay minerals accumulating into the B-horizon, this is why the A-horizon is often called the leached layer and the B-horizon is referred to as the enriched or mineral layer. Most horizons are noticeable because they differ from other soil layers in clay content, organic content, color, kinds and amounts of salts.

土壤的形成是由生物过程驱动的。微生物通过以不可思议的速度发生的大量复杂地球化学反应，创造了巨大的化学能量储备(Vernadsky，1939)。生物系统的催化作用通常可以使地质过程加速100多万倍(Westbroek，Bruyn，1996)。这种复杂的相互作用造成了有机物质的积累，腐殖物质进入土壤并形成粘土。这影响了垂直分层或土壤剖面水平地层的形成。通常，土壤剖面中有三个层位，称为A、B和C。A和B层位代表发生生物活动和粘土形成的真正发育土壤。C层是土壤形成的母质。C层仅受地球化学风化作用的影响，大部分原始矿物结构仍可识别。A层内的生物活动导致可溶性化合物和粘土矿物聚集到B层中，这就是为什么A层通常被称为淋溶层，B层被称为富集层或矿物层。大部分层位是显而易见的，因为它们在粘土含量、有机含量、颜色、盐的种类和数量上不同于其他土层。

Soils can be described as a self-organizing system that adapts and transforms parent mineral material into a developed soil profile that is best suited to the landscapes mineralogical, physical, biological and climatic conditions, maximizing geochemical potential, (John Slack 2010).

土壤可以说是一个自组织系统，它将母矿物材料调整并转化为最适合景观矿物学、物理、生物和气候条件的发育土壤剖面，最大限度地发挥地球化学潜力(John Slack，2010)。

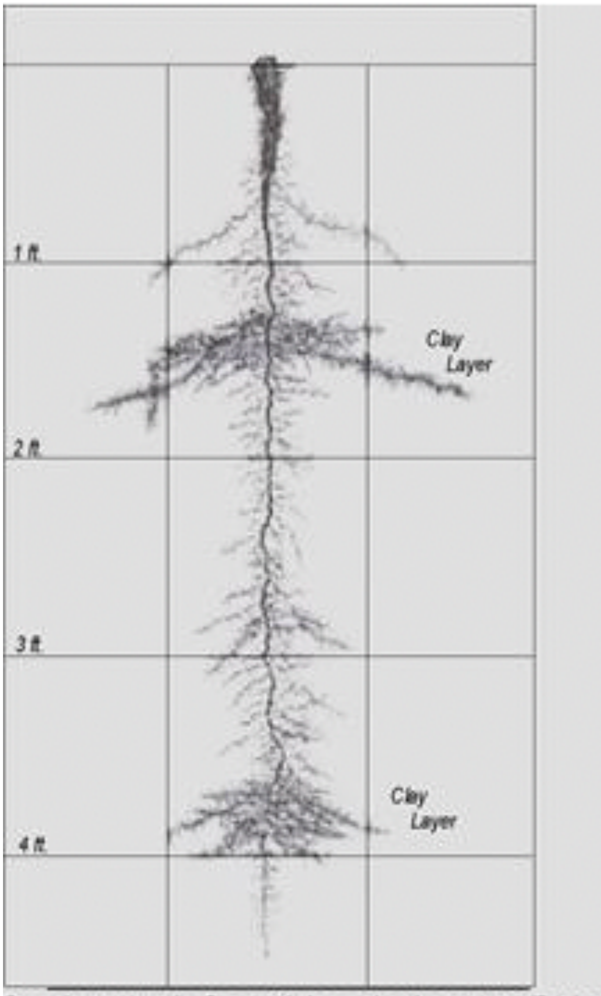
Most soil microbiology studies focus on the upper soil layer and do not take into account the increased thicknesses and bulk density of the lower profiles. In terms of correcting soil C and N content, it should be recognized that there is more organic matter below 25 cm then above it. Nitrogen fertility is concentrated in topsoil while active carbon is more pronounced in the soil substrates, (Paul E.A., Clark F.E., 1996)). This is referred to as the vadose zone (CO2 enriched). Without microbial and plant activity soil water would cease to be carbonated. The community of organisms living part or all of their lives in the soil has been described as the soil food web. The soil food web describes the critical role these mutualistic organisms play in nutrient cycling within the soil biota. Soil microbial communities represent diverse, complex, functioning microenvironments. The complexity of the pedosphere is represented by microbial numbers exceeding 1 billion and diversity of species in the tens of thousands per gram of soil, 99-99.9% currently unidentified, (Banfield, 1999). Both bacteria and fungi numbers decrease with depth, with fungi exceeding bacteria numbers in the subsoil. Fluctuations in biota populations commonly occur and in alluvial soils organisms are more abundant in the silt and clay horizons, (Paul 1996). Soil microorganisms have charged surfaces resulting in an attraction to clay aggregates. The largest soil microbial communities exist on charged clay particles. Microbial colonization and resulting soil structure is critical for the establishment of higher plants, (William, Welch, Banfield 1997).

大多数土壤微生物学研究侧重于上层土壤，没有考虑到下层剖面厚度和体积密度的增加。在校正土壤碳和氮含量方面，应该认识到25 cm以下的土层中有更多的有机物。氮的肥力集中在表层土壤中，而活性碳在土壤基质中更为显著(Paul E.A.，Clark F.E.，1996)。这被称为包气带(富含二氧化碳)。没有了微生物和植物活动，土壤水分将不再碳化。生活在土壤中的部分或全部生物群落被称为土壤食物网。土壤食物网描述了这些互惠生物在土壤生物群内养分循环中的关键作用。土壤微生物群落代表了多样、复杂、功能强大的微环境。土壤圈的复杂性表现为超过10亿的微生物数量，每克土壤中物种的多样性达数万种，目前仍有99 %至99.9 %尚未确定(Banfield，1999)。细菌和真菌数量都随着深度的增加而减少，地下真菌数量超过细菌数量。生物群的波动时常发生，冲积土壤中淤泥和粘土层中的生物更为丰富(Paul，1996)。土壤微生物具有带电表面，对粘土聚集体具有吸引力。最大的土壤微生物群落存在于带电的粘土颗粒上。微生物定植和由此产生的土壤结构对高等植物的建立至关重要（William，Welch，Banfield，1997）。

Second to photosynthesis in importance is the ion exchange and exchange reaction, (William, Welch, Banfield 1997). The formation of soil clays is accomplished by soil microorganisms. Clay minerals have the property of adsorbing certain anions and cations and retaining them in an exchangeable state, (Grim, 1968). In general, the most common exchange cations in the sequence of relative attractive forces are Al^{3+}, Ca^{2+}, Mg^{2+}, NH^{4+} ~ K+ > Na^{+}, (Juma 2002). Common anions in clay materials are SO^{4-}, Cl^{2-}, $PO_4{}^{3-}$, and NO^{3-}. Microbial colonization of soil aggregates take advantage of this phenomenon. Soil clay mineralogy is complex ensuring a wide diversity of cations and anions essential to productive microbial communities and higher plants.

仅次于光合作用的是离子交换和交换反应（William，Welch，Banfield，1997）。土壤粘土的形成是由土壤微生物完成的。粘土矿物具有吸附某些阴离子和阳离子并使它们保持可交换状态的性质(Grim，1968)。一般来说，相对吸引力序列中最常见的交换阳离子是Al^{3+}, Ca^{2+}, Mg^{2+}, NH^{4+} ~ K+ > Na^{+} (Juma，2002)。粘土材料中常见的阴离子有 SO^{4-}, Cl^{2-}, $PO_4{}^{3-}$, 和NO^{3-}。土壤团聚体的微生物定植利用了这一现象。土壤粘土矿物学是一门复杂的学科，确保了生产性微生物群落和高等植物所必需的阳离子和阴离子的广泛多样性。

Clays being tiny nanocrystalline particles and essential components of the earth’s surface are layer-type aluminosilicates, referred to as phyllosilicates. They arrange themselves into a structure of platelets similar to a deck of playing cards referred to as a colloid. This results in these compact nanocrystalline structures having very large surface areas. Illites having a specific surface area of 97.0 m2/gram and kaolinite 16.0 m2/gram. The best way to describe this incredible phenomenon is to tear the pages out of a book and place the torn pages side by side. The rather small book would cover a very large area and the number of pages would determine how large the area would ultimately be.



Sugar beet grown in fine sandy loam, showing root stratification in second and forth foot where layers of clay were encountered. (Weaver John E. (1926). *Root Development of Field Crops*, University of Nebraska, McGraw Hill, New York.)

粘土是微小的纳米晶体颗粒和地球表面的基本成分，是层状硅酸铝盐，称为页硅酸盐。它们把自己排列成类似于一副胶体纸牌的血小板结构。这导致这些紧凑的纳米晶体结构具有非常大的表面积。伊利石表面积为97.0 平方米/克，高岭石为16.0 平方米/克。描述这种不可思议现象的最好方法是把书页从书中撕下来，并把撕掉的书页并排放置。这本相当小的书将覆盖很大的面积，页数将决定面积最终有多大。

Absorption of water and nutrients occur over the extent of the root system but the majority of activity occurs in the younger and deeper roots, (Weaver, 1926). The study of root development by Weaver demonstrated the remarkable extent, diversity and importance to soil development and the role subsoil plays in plant nutrition. Experiments with a variety of cereal crops documented that plants in later stages of development received their nutrients and water from the deeper soil layers even when top soils were abundantly supplied with similar nutrients. Absorption of nutrients from subsoil affected considerably the protein and quantity of the yield.

水分和养分的吸收发生在整个根系范围内，但大多数活动发生在较年轻和较深的根系中(Weaver，1926)。韦弗（Weaver）对根系发育的研究表明，土壤发育的显着程度、多样性和重要性，以及底土在植物营养中的作用。对各种谷类作物的试验证明，即使表层土壤大量供应类似的营养素，处于发育后期的植物仍从更深的土层获取养分和水分。从底土吸收营养物质显着影响蛋白质和产量。

Weaver’s work contradicts the view that only the top 6 to 8 inches of soil is suited to plant life and subsoil only play an indirect role in plant nutrition. This notion only fits in geological settings where soil regimes have undergone intensive weathering. This requires distinct geological conditions coupled with water and high temperature. An example of this would be lateritic soils of humid tropical regions formed from acid granitic rocks (Leneuf, 1959). Weaver’s study of root habits clearly illustrates increased root development corresponding with mineral rich subsoil strata. Soil fertility recommendations never evaluate nutrient resources of subsoil. Not recognizing the role of soil substrates in plant nutrition has resulted in excessive fertilization and soil degradation.

韦弗的工作与仅顶部6至8英寸的土壤适合植物生长和底土仅在植物营养中起间接作用的观点相矛盾。这一概念仅适用于土壤经受强烈风化的地质环境。这就需要独特的地质条件加上水和高温。其中一个例子是由酸性花岗岩形成的潮湿热带地区的红土(Leneuf，1959)。韦弗对根系习性的研究清楚地表明了与富含矿物质的下层土壤相对应的根系发育有所增加。土壤肥力建议从不评估底土的营养资源。没有认识到土壤基质在植物营养中的作用导致了施肥过度和土壤退化。

Potentially the most critical factor affecting biologically mediated enhancement of mineral weathering effecting soil fertility is soil structure. There is a strong correlation between soil structure and organic content. Roots of higher plants stabilize larger soil aggregates, providing channels for water and oxygen. Fungus and bacteria dramatically increase contact area between biological and mineral surfaces significantly enhancing mineral dissolution. While the aggregation of soil particles by plants and microorganisms reduce physical weathering rates, increased mineral surface area, increased water retention increase chemical weathering. Microbial colonization and resulting soil structure is critical for the establishment of higher plants (Barker William W., Welch Susan A., Banfield Jillian F., 1997).

影响矿物风化生物促进作用且影响土壤肥力的最关键因素可能是土壤结构。土壤结构与有机物质含量有很强的相关性。高等植物的根稳定了较大的土壤团聚体，为水和氧气提供了通道。真菌和细菌显著增加生物和矿物表面之间的接触面积，显著提高了矿物溶解。而植物和微生物对土壤颗粒的聚集降低了物理风化速率，增加了矿物表面积、保水性和化学风化作用。微生物定植和由此产生的土壤结构对于高等植物的建立至关重要（Barker William W.，Welch Susan A.，Banfield Jillian F.，1997）。

Permaculture 永久培养

Cover Crops 覆盖作物

Compost 堆肥

Microbial Inoculants 微生物孕育

Peat Ammoniated Mineral Fertilizer 泥炭氨化矿物肥料

Peat Based Mineral Fertilizers is the principal agriculture use of peat in Russia. Referred to as "Peat Ammonia Mineral Fertilizer (PAMF) it is composed of milled peat and minerals (nitrogen, phosphorous and potassium). The mineral fertilizers are applied on the peat before extraction. Liquid nitrogen is added to the mass after extraction. PAMF is much more than a mixture of peat and minerals because the added ingredients are combining with active fractions of the peat hydrolyzing with water and forming new components. The organic components in PAMF are there to promote plant and soil microflora development and the assimilation of plant available mineral nutrients. Unlike mineral nitrogen fertilizer PAMF fertilizers, which are composed of 90% organic substances, effectively transforms added nitrogen into forms which are not detrimental to soil biological systems. This type of fertilizer increases soil's fertility by improving its physical, chemical and biological properties.

在俄罗斯，泥炭基矿物肥料是泥炭的主要农业用途。 被称为"泥炭铵矿物肥料（PAMF），它由磨碎的泥炭和矿物质（氮、磷和钾）组成。 提取前将矿物肥料施用在泥炭上。 提取后向液体中加入液氮。 PAMF不仅仅是泥炭和矿物质的混合物，因为添加的成分与泥炭的活性部分结合在一起，并与水一起水解并形成新的组分。 PAMF中的有机组分可促进植物和土壤微生物区系的发育以及植物可利用的矿物质营养物质的同化。 不同于矿物氮肥PAMF肥料由90％有机物质组成，可有效地将添加的氮转化为对土壤生物系统无害的形式。 这种类型的肥料通过改善其物理，化学和生物特性来增加土壤的肥力。

Microorganisms accomplish the decomposition of plant residues. The complex compounds are broken down to simpler ones referred to humic substances. Humic substances have been classified into three chemical groupings based on solubility: (1) fulvic acid – soluble both in acid and alkali environments, most susceptible to microbial attack; (2) humic acid – soluble in alkali but not acid, intermediate resistance to microbial attack and (3) humin insoluble in alkali and acid attack, most resistant to microbial degradation. It is recognized that the benefits of humus will accelerate water uptake, enhance germination of seeds, stimulate root growth, enhance growth of plant shoots and stimulate growth in plants and microorganisms. Commercial humate products claims that at very small application rates plant growth are enhanced but scientific tests of many of these products have failed to show any benefit to plant growth, (Brady 1999). Unlike predominantly NPK fertilizer and proprietary product programs employed in North America, PAMF addresses the functionality of the soil system. PAMF fertilizers, supplies the soil with degradable carbon and sufficient quantities of humic substances to stimulate microflora, which in turn enhances plant growth. The move to agricultural practices, which are harmonious within sustainable crop production ecosystems, will result in a move to PAMF fertilizers.

微生物完成植物残体的分解。复杂的化合物被分解为简单的腐殖物质。根据溶解度将腐殖物质分为三类：（1）富里酸——在酸性和碱性环境中均可溶，最易受微生物侵袭;（2）腐植酸——溶于碱但不溶于酸，中等抗微生物侵蚀和（3）胡敏酸——不溶于碱和酸的侵袭，最能抵抗微生物降解。人们认识到，腐殖质的益处将加速水分吸收、促进种子萌发、刺激根部生长、促进植物枝条生长并刺激植物和微生物的生长。商业腐植酸产品声称，在非常小的施用率下植物生长得到增强，但许多这些产品的科学测试未能显示对植物生长有任何益处（Brady 1999）。与北美地区主要使用氮磷钾肥料和专利产品计划不同，PAMF用于处理土壤系统的功能。 PAMF肥料，向土壤提供可降解碳和足够量的腐殖质以刺激微生物群落，从而增强植物生长。向可持续作物生产生态系统内和谐的农业实践转向PAMF肥料。

Composting with Peat 泥炭堆肥

The composting of peat with organic materials, vegetative and animal origins are called “peat compost”. In Russia after mineral fertilizers the principal use of peat is in composting. More than 100 million tonnes of peat per year are used for this purpose (Gelfer, 1985). The principal peat based compost products are cattle and poultry manures.

泥炭与有机物质、植物营养和动物源的堆肥被称为“泥炭堆肥”。在俄罗斯，排在矿物肥料之后，泥炭的主要用途是堆肥。 每年有超过1亿吨的泥炭被用于此目的（Gelfer，1985）。 主要的以泥炭为基础的堆肥产品是牛和家禽粪肥。

In Canada Mathur, Levesque, Dinal and Daigle (1985) have done the most work with composting peat. Their work demonstrated that peat was an excellent substrate for composting. Fish, crab and seaweed residues were composted with moderately decomposed peat (H4 on the Von Post scale). During the preparation of the compost 2/3 of the required water came from the peat. This excess moisture content was a contributing factor for compost microbial activity. The compost was comprised of 40% peat by volume. The same team conducted testing in Kapaskasing using peat, liquid and solid cattle manure, poultry manure, lime and sandy phosphate (Cargill Apatite).

在加拿大，Mathur、Levesque、Dinal和Daigle（1985）在堆肥泥炭方面做了大量工作。 他们的工作表明，泥炭是堆肥极好的基质。 将鱼、蟹和海藻残渣用适度分解的泥炭堆肥（Von Post的H4比例）。 准备期间2/3的所需水源来自泥炭。 这些多余的水分含量是堆肥微生物活动的一个促成因素。 泥炭体积占堆肥的40％。 在Kapaskasing进行测试的同一个团队使用了泥炭、液体和固体牛粪、家禽粪便、石灰和磷砂（嘉吉磷灰石）。

Other experiments demonstrated the use of decomposed peats did not give satisfactory results because of absorption difficulty and low exothermic fermentation. The content of carbohydrates decreases with the degree of decomposition and in these experiments highly humified peats were used. The use of slightly humified peat (H3-4) as a source of carbohydrates appears to work the best. Peats used for compost must have certain characteristics to effectively be utilized, table: 1 “USSR Quality Standards for Peat Used in Agriculture and Horticulture” outlines these differences. There are a number of key attributes peat possesses which no doubt will expand its use and are:

其他实验表明，由于吸收困难和低放热发酵，使用分解的泥炭没有给出令人满意的结果。 碳水化合物的含量随着分解程度而降低，且在这些实验中使用了高度腐殖化的泥炭。 而使用轻度腐殖泥炭（H3-4）作为碳水化合物的来源看起来效果最好。 表1:《苏联用于农业和园艺的泥炭的质量标准》概述了这些差异。 有一些泥炭拥有的关键属性，毫无疑问将扩大它的应用，它们是:

. a) CEC - peat has an exceptionally high CEC value, (60 to 160), making slightly to moderate humified peat excellent bedding and composting additive. 阳离子交换能力（CEC）——泥炭具有异常高的阳离子交换量（60至160），使轻度至中度腐殖泥成为优良垫层和堆肥添加剂。

. b) Absorbing Capacity – the ability to absorb and retain water is essential for good compost. 吸收能力——吸收和保存水分的能力对于良好的堆肥至关重要。

. c) Biodegradable Carbon – slight to moderately humified peat is an excellent source of carbohydrates resulting in soil microflora stimulation and composting qualities. 可生物降解的碳——轻微至中等腐殖化泥炭是一种极好的碳水化合物来源，影响土壤微生物刺激和堆肥的品质。

. d) Humic Content – moderate to highly humified peats are very high in humic substances. Applications of mineral rich, peat-based compost are a better way of crop fertilization. 腐殖酸含量——中度到高度腐殖化泥炭的腐殖物质非常高。施用富含矿物质的泥炭堆肥是作物施肥的更佳方式。

Spanish River Carbonatite Research Trails 西班牙河碳酸盐岩研究试验

Composting Trials 堆肥试验

Correcting Soil Acidification 改正土壤酸化

Plant Nutrition 植物营养

Microbial Responses - Wilfrid Laurier Master Thesis 微生物反应 - 加拿大劳瑞尔大学硕士论文

Ongoing Research 进行中研究

Required Research 所需研究

Conclusions 总结

Markets For Spanish River Carbonatite 西班牙河碳酸盐岩的市场

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