Biodeterioration of the RMS Titanic

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Titanic Research

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How marine organism activity will lead to the eventual destruction of the Titanic

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One of the great icons of the twentieth century was born April 15, 1912 with the sinking of the RMS Titanic. At her launching, this great ship was the largest liner ever built and carried the distinction of being the biggest, the best, and even claimed to be "unsinkable". The sinking was made even more dramatic by the striking of an iceberg on her maiden voyage, with over 1500 lives lost. This single event has become burnt into societies' consciousness as an image of arrogance and ignorance.

$^{+2}$ Fe^{+3} (O^{--}, OH^{-}, SO_4^{--})$_9$). Rusticles that have been recovered from the 1996 Expedition to Titanic have been analyzed by electron diffraction x-ray. This technique revealed that iron was the dominant atom within the range of atoms tested. The relationship within the bioconcretious structure is (dominant atom first): Fe > Na > S > Cl > Mg > Si > P > Mn. There is considerable variation in the elemental composition of the rusticles tested, however, this reflects the heterogeneous nature of the structures themselves.

in situ showed, visually, that the rusticles have a concrete looking exterior however, when approached and, when touched or disturbed through mechanical means, proved fragile and commonly shattered into numerous pieces, spewing a red, powder-like material into the surrounding water. This phenomenon was examined closer in a laboratory setting, using recovered rusticles. When growth occurred in the laboratory, the rusticles were fed various selective culture media through implanted hypodermic syringes simulating organic loading in the oceanic environment. Growth occurred very slowly but it was noted that there was a continuous release of material resembling the powder-like material first observed in situ, through the ducts leading from the structural water channels. This material, when dried, resembles red dust, having an iron content, on average, of 20+/-5%. Additionally, there were releases of biocolloidal yellow slimes with an average iron content of 8+/-3%. These releases totaled between 0.02 and 0.03% of the rusticle's biomass per day. If this were to be repeated in situ, tests indicate that it would take between nine and fourteen years for the same amount of iron to be released from the rusticles as equivalent to the amount of iron being held within the rusticles structure. From the 1996 surveys, it was determined that there was approximately 650 tons (dry weight) of rusticles on the outside of the bow section of the wreck.

From this, it can be extrapolated that a daily loss of iron, as red dust and yellow biocolloids, of between 0. 13 and 0.20 tons per day could be occurring from the wreck. Further extrapolation reveals that iron in the bow section, assuming 20,000 tons of iron, and that the rusticles were removing the iron at a constant rate, could be totally exported into the environment as red dust and biocolloids in approximately 280 to 420 years.

Key in determining how long the Titanic may remain intact is the rate at which these biologically-driven rusticles will grow and extract iron from the steel plating of the ship. To examine this phenomenon, four IPSCO Test Platforms were placed down at the site of Titanic, in 1998. Each platform has three different types of maritime steel, each represented by five coupons, which have been either twisted, hammered, tempered or burnt, including a control sample. These platforms are still at the wreck site and early reports indicated that the rusticles are growing over the test coupons. When recovered, the rusticle growth and resident amount of iron in the coupons will be used to assess the rate at which iron extraction is occurring, the residence time in the rusticle for the iron and finally, the amount of iron already exported to the oceanic environment In addition to the IPSCO Test Platforms, there is a need to understand the nutritional factors influencing the growth of rusticles. On both the 1996 and 1998 expeditions, there were periods when the "sea snow', a mixture of biocolloids and zooplankton, was so intense that it resembled a blizzard on the prairies. This sea snow originates, in part, from the deep scattering layer located approximately 400-1000 meters below the surface, and partly from the growths over the ocean floor. After such a "snow fall", the rusticles become covered with a gentle coating of white slime that presumably, is able to be consumed by the rusticles through the ducts that perforate the outer structural coating.

There appears, at this time, to be evidence not of a catastrophic structural failure about to occur in the near future, but rather of a gradual collapse that would follow a somewhat predictable pattern. In simple form, this pattern would include (in probable chronological order) the loss of all structures above the hull, collapse and disintegration of internal decks and walls, exposure of all of the heavy mechanical equipment in the bowels of the ship (e.g., boilers, turbines), fracturing and collapse of the hull plates, exposure of the double bottom hull and the final disappearance of the remaining resident structures. This chain of events probably would take many hundreds of years, long after the RMS Titanic had ceased to be a recognizable structure.

For science, the RMS Titanic now provides an opportunity to learn from the deep oceanic degradation of steel structures. At this site, the deterioration of structures still has many stories to tell. The debate between fact and fiction reigns on. Claims range from the steels deteriorating to become as thin as sheets of newspaper, having the same strength as the chocolate in a candy bar, to the steel strength being slowly yielded to the iron-devouring rusticles. Ongoing science at the site and the proper comparison of the myriad of images from 1986, particularly those between 1998 and 2000, can aid in addressing the validity of these claims.

In addition to the desire by many to make the RMS Titanic a protected memorial site, there remains a

continuing need for dedicated science and archeology to learn as well as to remember. From a microbiological standpoint, research and development could further address the issues surrounding the rusticles as very unusual life forms. The ongoing controversy over the RMS Titanic carries with it the possibility of profound consequences. To learn from this tragic disaster, still within the halls of memory, is an essential legacy of the RMS Titanic. As one of a large number of sadly sunken ships, the RMS Titanic stands apart from all of the others through representing the ending of one complete chapter in the history of humankind. RMS Titanic has earned the right to become a site to be remembered, revered and respected and from which knowledge should grow rather than simply become yet another site to be plundered.

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Microbiological Scientific Activity on the RMS Titanic

1996 to 1998

RMS Titanic Inc., in conjunction with Discovery Channel, organized an expedition in 1996 that would begin to address the science associated with the ship, from the disaster itself, onwards as she sails into archeological history. The questions asked of me were related to the observed deterioration of the ship's structures and the possibility that these events were orchestrated by microbes. The following events were undertaken in the above stated time period in an attempt to begin to understand the nature of these events:

> ^{TM} tests on the bridge deck to determine whether heterotrophic aerobic and iron-related bacteria were active on the ship. The tests were brought back in 3 and 12 days respectively. Both BART^{TM} tests showed that there was bacterial activity belonging to each of these two bacterial groups.

1998

Experiment 5: It was evident from the previous work done in 1996 and ongoing laboratory studies, that the steel structures on the ship are biodeteriorating as a result of the rusticles removing iron from the steel. Four IPSCO Steel Platforms were placed on the ship:

(1) Just forward of the right engine in the stem of ship on a rusticle flow from the double bottomed hull;

Each platform had 15 metal coupons separated into three groups (mild steel, AH36 and EH36, modem maritime steel). Within each group of five coupons, one was a control while the others were either hammered, twisted, burnt or tempered. The coupons were arrayed in a manner that would encourage rusticles to grow over the steel. After seven days, it was reported that growth was occurring, however there has been no imagery received that would indicate the state of these platform since the 1998 expeditions.

TM tests conducted in 1996, was conducted in 1998. Miniature laboratories, called BART^{TM} platforms, were placed at the same sites as three of the four IPSCO Test Platforms. All three of the BART^{TM} platforms were recovered during the expedition and all showed evidence of active bacterial growth.

Extensions to the Experiments: 1998 to 2000

> Educational: Cooperation with firstly, RMS Titanic Inc., and later with Maryland Science Center, has led to the bringing of some aspects of the science into the public forum. Specifically, in 1999, aspects of this research were introduced into the Titanic Exhibitions in Hamburg, Germany and Zurich, Switzerland, through RMS Titanic Inc. Also in 1999, there began an ongoing dialog with Maryland Science Center for

the incorporation of some elements of this work into "Titanic Science, Depths of Discovery" that is due to open in November 2000. Within a matter of weeks a local exhibition will open at the Saskatchewan Science Center title "Titanic, the Saskatchewan Connection". The Maryland exhibition, which will tour and is supported by the National Science Foundation, will include many aspects of the scientific studies including some of the following:

> Walk through a rusticle (1 6' x 12' structure) through which visitors can walk and see the different structures that have been seen in these organisms;

Progress from 1998

1. Patent application for the use of electromagnetic forces to relocate microbial fouling events in water, oil and gas wells.

Challenges and Achievements

RMS Titanic Inc., in conjunction with Discovery Channel, organized an expedition in 1996 that would begin to address the science associated with the ship from the disaster itself onwards as she sails into archeological history.

Two arenas of conducting science at the site of the RMS Titanic relate to the challenges, as well as the achievements. Historically, the science relating to the site began early on with the realization that there was an abundance of valuable information from a variety of disciplines, not only forensic evidence, that could be used to determine the manner is which the ship sank, broke up and came to rest on the ocean floor amid a large debris field. This evidence was in the field of the marine architects and the metallurgists who concentrated on the pathway of events that had enacted on that fateful night in 1912. Archeologists

were intrigued by the various states of decay or pristine preservation that existed in the various artifacts observed both in the debris field and on the ship. Over 5,000 artifacts have been recovered and restored with patience and care.

The manner in which the RMS Titanic has burnt into the global social consciousness made has made this ship more than any other, the center of attention. As a result there were a number of expeditions to the site often with the mass communication media heavily involved. Major events at the site include the IMAX expedition (1991), James Cameron (1995) and the Discovery channel/NBC (1996 and 1998). These latter two events incorporated a significant level of science, primarily to provide interesting dimensions to the ongoing storyline that is the RMS Titanic. The support for the science was therefore designed to educate and interest the audience. In 1997, the documentary "Titanic, Anatomy of a Disaster" became the highest rating episodic show on the Discovery channel, in part, because it was a fine weave between history, the nature of the disaster and the state of the ship today. This documentary focused on the science and even showed experiments going down to be left on the ship for a period of time. In 1998, the science was expanded with more experiments going down to the ship. Funding came from the Discovery channel and was limited to preparing the experiments and ensuring that they could be placed at the appropriate sites. There was no ongoing funding to continue the research. For myself, I am a major shareholder of a small successful biotechnology, Droycon Bioconcepts Inc., DBI, that manufactures the BART^{TM} water test kits for nuisance bacteria as well as research and development activities. Because of internal funding from this source, the research on the microbiology of the RMS Titanic was able to proceed. No attempts were made to obtain external funding except for the Society of Naval Architects and Marine Engineers (forensic committee, SD-7) who gave $8,500 in support to the Universities of Regina and Daltech in Halifax. Internal funding has amounted to contribution, in-kind, of US$50,000 per annum, but the products of that effort have been woven into the other research activities that are also ongoing at DBI. This "cross pollination" of projects at DBI is partly because of the area of applied microbial ecology that DBI has developed an expertise in. These are briefly:

Recovering water wells from severe biological fouling (plugging). The bacterial consortia down water wells closely resemble the rusticles at the RMS Titanic. Through beginning to understand the nature of rusticle growth and their affinity to particular electrical charged sites it has become possible to develop a new (patent pending) treatment to rehabilitate plugging water wells more economically.

Ironically oil wells need to have the water entering (and blocking) the production flow of oil from a well plugged off. Research is now ongoing literally in growing rusticles down oil wells to aid in the plugging off the water before it enters the oil well. This work is in the advanced stage of development approaching the field testing stage.

^{TM} test systems is growing and also becoming automated. In 1996, a., prototype computer test system was successfully used on the Ocean Voyager research ship and functioned through a laptop computer even through the Atlantic storms. Since then the whole hardware has been simplified and will be shortly marketed as the BART$_{SCAN}$^{TM} system and will be subjected to EPA

verification as an alternative testing technology for the biochemical oxygen demand 5-day test.

Rusticles are forms of living porous concrete and, as such, offer an opportunity to determine to potential role of microbes in the "curing" of concrete. Parallel studies conducted jointly with Canada Agriculture (PFRA) in Regina found that the use of inoculated bacteria in the making of Portland concrete gave a similar strength along with a more porous structure when compared to sterile control concrete. At this time DBI does not have the funds to pursue this project but it remains a tantalizing challenge.

General Comments:

The RMS Titanic has created, in my mind and the way I view the world, many differences since the first dive in 1996. From that sad tragedy is now emerging the challenges of learning of new life forms, extreme environments, of the vulnerability of steel, and of Nature gradually recycling. Here, Nature is retrieving and returning that which was the RMS Titanic, back into the myriad of living cycles that form life. The list of possible benefits from the science blossoming on the ship could be: more sustainable ships, stronger concretes, better steels, new uses for electromagnetic forces, an understanding of a new group of life forms previously never recognized nor understood, and possibly new drugs. All of these possibilities emerge from the "ship of dreams" but how would this be done and who would do it?

Summary Statement

D. Roy Cullimore. Sunday, September 3, 2000

I have visited the RMS Titanic site in both 1996 and 1998 in the submarine Nautile as a part of the expeditions that were organized in those years. My role, as a microbiologist, was to determine the nature of the growths that were developing on the bow section of the RMS Titanic. These growths, known as rusticles, were found to be living, not a single species of a plant or animal, but rather a complex of

microbial communities living within an iron-rich and calcium-deficient porous concrete-like home. They were found to be extracting iron from the steel of the ship and then exporting that iron into the oceanic environment as red dust and yellow colloids (slimes). This was discovered in laboratory based studies using rusticles recovered from the site. There appeared to be considerably more rusticle-type growths in 1998 than in 1996 and an examination of the video images from those two expeditions revealed an increase of approximately 30%. This would indicate that the removal of iron from the ship is an ongoing and accelerating activity. In 1998, the IPSCO Steel Test Platforms were placed on the ship at strategic locations to determine the rates of iron loss that was now being experienced. Unfortunately this activity was not of interest to the current administration of RMS Titanic Inc. and no attempt was made to either provide photographic evidence of the state of the steels coupons on the platforms or offer to retrieve one or more of these platforms. No request was made to the company because there was no interest expressed in continuing the science and attention was totally focused on artifact retrieval. In contrast to this, the Maryland Science Center (MSC) with the support of the National Science Foundation is organizing a science-based exhibition, which complements the artifact-based exhibitions being organized by the company. In support of the MSC attempts have been made to begin to generate a predictive understanding of the speed with which the RMS Titanic bow section is collapsing. Based upon available video imagery up to 1998, there can be projected a rate of biodeterioration that would be partially dependent on the growth rate of the rusticles both inside and outside the steel, and also on the rate at which the iron is being exported into the oceanic environment The table below summarizes the potential losses of iron from the bow section under various conditions.

Estimated Time (calendar year, AD) Frame

For the Losses of Iron from the Steel Bow Section, RMS Titanic

Percentile Steel Loss under various Growth Conditions

Growth Rate		20%	30%	4
Extreme	2020	2026	2034	2
High	2032	2048	2056	2
Moderate	2050	2068	2088	2
Low	2098	2212	2326	2

Note

In the event that the biodeterioration is proceeding at an even faster rate than the "extreme" condition listed in the above table than there must have been some very dramatic changes in the environmental conditions at the site. These changes would have had to stimulate the growth of the rusticles one or two orders of magnitude beyond this estimate. This might occur at the site if there were to be a sudden increase in the available nutrients (e.g., "sea snow', dissolved organic matter and/or slime from the ocean floor) to accelerate the growth or there were dramatic changes in the environmental conditions at-site. For example, sudden rises in temperature, shift in the pH, or changes in the reduction-oxidation potential.

Publications

Pellegrino, C. and D. Roy Cullimore (1997). The Rebirth of the RMS Titanic: A study of the Bioarcheology of a Physically Disrupted Sunken Vessel. Voyage 25, June, pp.39-46.

Personal Biography of Denis Roy Cullimore, Ph.D., Registered Microbiologist (C.C.M.)

1970 - 79: Pesticide interaction with soil microorganisms; detection of iron bacteria in water wells, presented two series of six television documentary shows on microbiology in the CTV "University of the Aie' series.

TM

TM tests and consulting activities, co-invented three approved (U.S.) patents including new coliform test, synthesis of in-ground biological barriers, and an alternative bacteriological testing procedure, developed a predictive method for deter-mining the rate at which water wells become fouled (well fouling index), designed part of the "Titanic Science, Depths of Discovery" exhibition for the Maryland Science Center with partial funding coming from the National Science Foundation and due to open late in 2000, developing a new method for conducting rapid and accurate biochemical oxygen demand tests using the BART™

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