REVISED STATUS REPORT: TALUSSNAIL SURVEYS AND LITERATURE REVIEW
IN THE
ROSEMONT PROJECT AREA AND VICINITY

Prepared for: Rosemont Copper Company
Prepared by: WestLand Resources, Inc.
Date: September 17, 2009
Project No.: 1049.14 350 350

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Memorandum

To: Beverly Everson
Cc: Tom Furgason
From: Kathy Arnold
Doc #: 012/10 — 15.3.2
Subject: Transmittal of Talussnail Information
Date: March 17, 2010

Rosemont is transmitting the following documents to the Forest Service, most of these documents have been provided to the various biologists during site visits but have not been officially provided to the Forest:

1. Revised Status Report: Talussnail Surveys and Literature Review in the Rosemont Project Area and Vicinity, WestLand Resources, Inc. dated September 17, 2009
2. Report in the University of Arizona Science-Engineering Library and also Special Collections: Invertebrates (Other than Insects) of the Rosemont Area, Walter B. Miller, dated 1978
3. Mollusca of the southwestern states, Pilsbry and Ferriss, pages 51, 68, 69, and 90, dated 1923
4. Land of Mollusca of North America, Henry Pilsbry, dated 1939

We are providing these is hardcopy as well as electronic format.
1. INTRODUCTION

WestLand Resources, Inc. (WestLand), has been retained by Rosemont Copper Company to conduct a variety of baseline biological surveys in the vicinity of their proposed open-pit copper mine and associated processing facilities at the north end of the Santa Rita Mountains in Pima County. A species referable to the Rosemont talussnail (*Sonorella rosemontensis*) was identified by resource agencies as a species of interest that may be present in the mine vicinity. Species within the genus *Sonorella* (*Helmithoglyptidae*) are commonly referred to as talussnails. As part of ongoing baseline biological studies, WestLand is conducting studies of *Sonorella*, including surveys to determine the distribution of *Sonorella* within and in proximity to the proposed copper mine. WestLand is also conducting morphological analyses to identify which species of *Sonorella* occur in the vicinity of the proposed mine (Figure 1; Appendix A). The purpose of this report is to provide a summary of the work that has been conducted between July 2008 and the present and to provide the status of work that is ongoing.

The report is organized in four sections and includes the following: this introduction in Section 1; a description of the field surveys and the literature review, and the results of those efforts, in Section 2; the status of ongoing taxonomic studies in Section 3; and a list of references in Section 4.

As part of the review of previous unpublished and published documents pertaining to *Sonorella* species in the Santa Rita Mountains, and particularly near the proposed mine site itself, we use the names of the snail species as they appear in the documents. We use the binomial *S. rosemontensis* in this document as it is used in these previous documents. We do not use the taxon *S. rosemontensis* beyond its use in previous documents. Pending completion of our analyses of the *Sonorella* specimens collected in the vicinity of the proposed mine, adjacent areas of the Santa Rita Mountains, and adjacent mountains, we remain neutral with respect to the validity of this taxon.

2. FIELD SURVEYS AND LITERATURE REVIEW

2.1 FIELD SURVEYS

In 2008, WestLand conducted field surveys for *Sonorella* from July 14 to October 1. The surveys coincided with the monsoon season. Some searches occurred during a daytime local storm, others the morning after an intense nighttime storm.

We adopted two approaches to searching for *Sonorella*. Within the proposed mine area, we walked along canyon bottoms while visually searching adjacent slopes for rocky outcrops and particularly rock accumulations (talus). The routes searched within the proposed mine area are provided in Figure 2. The other approach was to visit talus slopes visible on Google Earth® or visible in the field. During both approaches, when rock accumulations were found that had interstitial spaces between rocks, scattered locations on the talus were searched for snails or shell (Figure 2). Within the talus, rocks were removed at selected locations to a depth of 2 feet to search for snails or shells not visible from the surface. A site was determined
to be occupied by *Sonorella* if live snails were found or evidence of snails was found (i.e., a *Sonorella* shell).

Notes were made describing the general conditions of the talus slopes, with special attention to collection locations.

We found *Sonorella* generally near the edges of talus slopes, where shrubs and small trees occurred and where there was a correspondingly greater accumulation of leaf litter. Near the edges of the talus, *Sonorella* probably would not have to move as deep into the talus to find areas of higher humidity. The central parts of the slopes were searched for *Sonorella*, but very few were found in these areas. We observed *Sonorella* snails feeding on lichens, plants, and leaf litter, particularly lichens. They may also feed on fungus growing in leaf litter below the surface. In Agua Caliente Canyon during one summer rain, two *Sonorella* were observed mating and another was found beside a cluster of snail eggs. General survey routes and specimen collection locations within the Rosemont holdings are shown on Figure 3.

Shells of dead *Sonorella* were collected from 26 localities in the Santa Rita Mountains. Approximately 25 live *Sonorella* were collected (under Arizona Game and Fish Collecting Permit #SP637280), including *Sonorella* from the west slope near Gunsight Pass, from McCleary Canyon, in Gardner Canyon, in Agua Caliente Canyon, and on the slopes of Mt. Hopkins. Most of these *Sonorella* are still alive in captivity; examination, documentation, and preservation of their genitalia for species identification are planned in the near future. Live aestivating *Sonorella*, shells, and shell fragments were collected and their locations recorded with a handheld GPS unit. Photographs were taken of the *Sonorella* *in situ* and on the slopes and microsites where they occurred.

Key findings of our 2009 field surveys include the following:

- **Distribution considerations**
  - Most talus slopes that support *Sonorella* are deep, with loose clasts several decimeters to almost a meter in diameter.
  - Review of available geologic literature and historic photographs indicate that talus features are persistent elements in the landscape.
  - Space between the rocks is an important feature of talus for *Sonorella* because it allows for vertical migration of the snails in response to climatic variation.
  - Larger talus slopes west of the ridge are lined or nearly lined with shrubs and small trees. This increase in vegetation along the edge of talus slopes contributes directly to leaf litter that accumulates along the sides of the talus slope.
  - The soil beneath the talus slope is likely much wetter due to reduced evapo-transpiration (because of the lack of vegetation growing directly on the talus and because the talus rocks act as a deep mulch).
Sonorella are not limited to deep talus slopes and can be found in canyon systems with extensive rock rubble.

- There are only limited areas of talus or other suitable locations for Sonorella within the proposed impact footprint.

- Within the northern portion of the Santa Rita Mountains the best developed and most extensive sites for potential Sonorella habitation are west of the ridge and outside of the proposed mine site.

### 2.2 Literature Review

#### 2.2.1 Site Characteristics

Land snails from the arid southwest have numerous microhabitat requirements, but very little detailed information is available for individual species of talussnails (Kroll et al. 2003, Wiesenborn 2003). Pilsbry (1939) noted that species within the genus Sonorella are primarily rock snails and that talus slopes (or rock slides) and rocky outcrops (i.e., outcrops that are sufficiently broken or fractured to provide refuge sites) are the sites where these snails are most commonly collected. Hoffman (1990) described site characteristics of Sonorella species in the Pinaleño Mountains as consisting of rock slides, canyons, and/or talus slopes that tend to face northwest. Based on his experience searching for snails in the Pinaleño Mountains, Hoffman reported that the most favorable talus slopes are those consisting of a layer of rock at least 4-feet deep, or at drier locations, a rock layer up to 8-feet deep. Pilsbry (1939, p. 268) indicated that Sonorella snails in the drier mountains of Arizona can be found 1 to 2 feet below the surface, usually in talus slopes composed of igneous rocks, quartzite, or rarely limestone. Hoffman (1990) found that talus slopes occupied by Sonorella were free from choking debris or litter. It is unclear whether the entire talus slope was free from choking debris. In contrast, Pilsbry (1939) believed that some of the best locations to search for Sonorella were at the edges of talus slopes where trees and scattered bushes were present and provided fallen leaves which produce “cryptogamic food.” In our 2008 and 2009 surveys, we observed Sonorella during and after rains foraging on Xanthoparmelia, a foliose lichen abundant on the rocks of talus slopes in the Santa Rita Mountains.

#### 2.2.2 Taxonomic Considerations

The genus Sonorella was first described by Pilsbry (1900) and several species had been discovered by Pilsbry by 1909. As a result of geological conditions (isolated mountain ranges) and an overall drying trend occurring throughout the Pleistocene period, the formerly widespread land snails in the genus Sonorella have split into numerous geographically isolated populations distributed across the southwest (Pilsbry 1939). Sonorella rosemontensis was described as a new species by Pilsbry in 1939 (p. 348-349). As described, it was a narrow endemic, known only in the “northern end of the Santa Rita Mountains near Rosemont (J. H. Ferriss), Type 166642 A.N.S.P.; Helvetia; Greaterville” (Pilsbry 1939).

In his treatment of 52 species of Sonorella in 1939, Pilsbry considered the morphology of a number of features of the genitalia, including the verge and penis morphology and size and the size of the vagina. Pilsbry
also considered shell size, shape, and coloring, and microscopic sculptural elements (rugae) on the embryonic shell. Pilsbry and Ferriss (1923) had originally ascribed to *S. hesterna* the type specimen Pilsbry recognized in 1939 as *S. rosemontensis*. For *S. rosemontensis*, Pilsbry regarded the descending threads\(^1\) of the embryonic shell to set it apart from *S. hesterna*. Pilsbry also noted that the shell of *S. rosemontensis* is similar to *S. walkeri aguacalientensis*; but for the strongly spirally plicate verge, *S. rosemontensis* “would hardly be separated from *S. walkeri*” (p. 349).

Pilsbry assigned *S. rosemontensis* to the subgenus *Sonorella* s. str. which was one of four subgenera recognized by Pilsbry. He notes that the species of *Sonorella* s. str. “are the most numerous and difficult group, differential characters are often feebly developed and specific limits uncertain” (Pilsbry 1939, p. 273). Pilsbry explicitly recognized that his taxonomy of this group was provisional and dependent on the extent of the collections available.

Nearly 30 years later, in his revision of the genus, Miller (1967) recognized 68 valid species of *Sonorella*, 57 of which were present in Arizona. *Sonorella* species occupy over two-thirds of the state of Arizona, excluding the extreme southwest and parts of the north and northeast (Bequaert and Miller 1973). The localized distribution pattern of *Sonorella* species contributes to concern over the conservation of species within this genus. In his review of the genus, Miller (1967) considered *S. rosemontensis* to be a valid species, although he pointed out that his dissection of genitalia of an adult specimen was very different from the drawing by Pilsbry. Miller (1967) believed that Pilsbry had inadvertently dissected a specimen of *S. tumamocensis linearis* and labeled the figure as *S. rosemontensis* (Miller 1967).

As part of Miller’s re-evaluation of *Sonorella* species, he applied Ernst Mayr’s concept of species to *Sonorella*. For Mayr (1942), a species was not just a collection of individuals that were morphologically similar, but a population of interbreeding or potentially interbreeding individuals whose off-spring were fully fertile. “Potentially interbreeding” extended the definition of species to those populations that might now be isolated geographically, but if reunited, these populations could still interbreed with full fertility in the offspring. Miller applied Mayr’s species concept and collected immature snails from the type localities of *magdalenensis*, *arida*, *tumamocensis*, and *linearis*. He found that these snails, once they reached maturity in captivity, “interbred freely, producing viable F1 offspring, which in turn produced many F2 snails; further, his dissections of snails of *magdalenensis*, *tumacacori*, *tumamocensis*, *arida*, and *linearis* from their type localities showed no significant difference in their genitalia” (Bequaert and Miller 1973). Based on Pilsbry’s later revisions, Miller’s examination of the genitalia, and Miller’s experimental crosses between snails from the different type localities, Pilsbry and Miller subsumed at least eight of Pilsbry’s earlier species of *Sonorella* into the species *S. magdalenensis*.

In the mid-1970s, Miller (1978) conducted a broad invertebrate resource survey (excluding insects) in the “Rosemont Area.” A central goal of this survey was aimed at re-locating and documenting the presence and distribution of *S. rosemontensis*. Miller (1978) referred to his previous field searches in 1965 and 1966 that found *S. rosemontensis* on the west side of the ridge near Helvetia Pass (Gunsight Pass), but searches by him

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\(^1\) Some species, provided the shells are relatively unweathered, show sculpturing in the outer-half whorl of the embryonic shell. These sculptural elements can be parallel, thread-like, and curve inward as growth proceeds. For some other species, the sculpturing can even be pleated or braided in its appearance.
at the same time failed to find any specimens east of the ridge. Miller (1978) looked for *S. rosemontensis* in the Rosemont area as well as on the west slopes of the ridge that includes Hart’s Butte. Near Gunsight Pass, he found “several specimens referable to *S. rosemontensis*. Careful examination of shells and reproductive anatomies revealed no significant differences from *S. walkeri* Pilsbry and Ferriss, which is common farther south and at higher elevations in the Santa Rita Mountains, particularly in Florida, Madera, Josephine, and Gardner Canyons. It is the opinion of the author [Walter Miller] that *S. rosemontensis* is at least conspecific with *S. walkeri* and may possibly be a synonym” (Miller 1978). Miller doubted that *S. rosemontensis* was a distinct species, used both shell and genitalia in his evaluation, and was (likely) as familiar with the anatomy of genitalia of *Sonorella* as Pilsbry.

Miller goes on to report that “every effort was made to look for populations of this species in the Rosemont area; none was found” (Miller 1978). He visited about 15 or more locations on the east side of the ridge, and a total of 23 locations. Miller found *S. rosemontensis* on the west side of the ridge, but not the east side. This is an issue because Pilsbry (1939) identifies the type locality as simply “near Rosemont,” and he recognizes this species extending to Greaterville and Helvetia.

Until the present, the specific locations of Stations 48 through 51 where *S. rosemontensis* was originally collected remained unclear. WestLand has uncovered the text that documents the location of these stations. The text was written by Ferriss who drove an automobile through the American Southwest while collecting snails. His trips spanned almost two decades; our understanding of these trips comes from the resulting publications by Pilsbry and Ferriss. Ferriss sent the majority of his specimens to Pilsbry at the Academy of Natural Sciences of Philadelphia (ANSP). In 1923, Pilsbry and Ferriss briefly described the stations where Ferriss had collected snails during his 1917 road trip through the Southwest. The stations were numbered sequentially during a particular trip, but the numbering sequence of stations would start at number one again for a subsequent trip to the Southwest. By their convention, both Pilsbry and Ferriss identified a particular station by number and at least in their publications, parenthetically or with a hyphen, by year. The locality of *S. hesterna* (which later was described by Pilsbry as *S. rosemontensis*) was described as “Station 49 – 52 (1917)” on page 60 by Pilsbry and Ferriss (1923) and “northern end of the Santa Rita Mountains, Station 49 (1917) near Rosemont” on page 90 of the same publication. The year 1917 does not refer to the year of a publication; it refers to the year the specimen was collected.

Pilsbry (1939) recognized the type locality of the type specimen (ANSP 166642) of *S. rosemontensis* (formerly included as *S. hesterna*) as Station 49. Confusion has arisen because Stations 48 to 52 were not described on page 51 in Pilsbry and Ferriss (1923). Although, using their usual format, they had included descriptions for each station up to and including Station 47 (in the Sierrita Mountains) and continued with Station 53 (Pictured [sic] Rocks in the Tucson Mountains). We recently located the missing station descriptions in the original typed correspondence from Ferriss to Pilsbry that is in the archives of the ANSP. We have included a photocopy of the page (Appendix B) that includes the Rosemont Stations 48 to 51.

With the brief descriptions of the four stations and knowledge of the roads and camps of 1917, we are able to narrow down where Ferriss was when he made his collections in the northern end of the Santa Rita Mountains.
• Rosemont, the town, was essentially nonexistent by 1917. However, during the latter part of 1916 and through 1917, the Narragansett Bay Mine was very active and produced most of its ore during this brief 1½-year phase. The “camp” referred to in the description of Station 48 is most likely the Narragansett Bay and Daylight Mines, and adjacent workings. It was a mining camp (not town), that included not only the workings but informal arrays of tents in the vicinity to accommodate as many as 200 to 300 miners in 1917. Station 49, “in saddle above 48,” becomes Gunsight Pass. Stations 50 and 51 are the larger talus slopes within 150 meters southwest of Gunsight Pass and in view of Helvetia.

• Because Ferriss traveled by automobile (which he referred to as the “machine”), he was restricted to collecting along roadways. The earlier geology map by Frank Schrader during his visit in 1909 to the Helvetia-Rosemont mining districts of the Santa Rita Mountains shows roads but is drawn at a scale too large and unrectified to identify with precision Ferriss’ route. It is a geology map by Thomas (1931) of the Narragansett Mine and adjacent mines surveyed and drawn between 1930 and 1931 (13 or 14 years after Ferriss was in the area) that provide the best detail of the route of the road. Once again, Station 48 would be small quartzite “slides” south of the Narragansett-Daylight mining camp and the road, near the ridgeline. Stations 49 to 51 would be at the point where the road passes through Gunsight Pass (Station 49) and to the south of the road as it begins its descent towards Helvetia (Stations 50 and 51).

The key findings for the taxonomic status of Sonorella are as follows:

• There are only two Sonorella species recognized as occurring in the Rosemont/upper Helvetia area of the Santa Rita Mountains: S. rosemontensis (S. walkeri) and S. magdalenensis. It is Miller’s opinion that, “S. rosemontensis is at least conspecific with S. walkeri and may possibly be a synonym” (Miller 1978).

• The taxonomic status of the genus has been in a state of flux, with Pilsbry lumping many of his original species into fewer taxonomic groups as he continued his data collection and Miller (1967) continuing this trend by subsuming a handful of Pilsbry’s species (Pilsbry 1939) into S. magdalenensis.

• In 1978, Miller (1978) reported no S. rosemontensis east of the ridgeline, within what is currently the proposed mine footprint.

• The type locality of S. rosemontensis is at Gunsight Pass.

3. ONGOING TAXONOMIC STUDIES

Each live snail encountered during WestLand’s field surveys was collected and kept in captivity for further examination. To obtain positive identifications of some of the collected snails, a limited number of dissections were performed under a microscope. The genitalia of each animal, particularly the verge, were sketched.
Most of the specimens collected in our surveys were empty shells (or “bones,” using the terminology of Pilsbry and Ferriss). However, the literature on the genus *Sonorella* provides no morphometric analyses of the shells of species, nor a statistical evaluation of the reliability of ascribing a particular individual to a species using only shell morphology.

A literature review of the mathematical description of logarithmically coiled shells was made. Sources consulted include D’Arcy Thompson (Canto Edition 1992), and numerous papers including Raup (1961, 1966, 1972), Madec et. al. (2003), Lleonart et. al. (2000), Kohn and Riggs (1975), and Van Osselaer and Grosjean (2000). Other papers were consulted, but these cited papers are the basis for the methods developed for this project. Raup’s papers on the coiling geometry in gastropods (1961, 1966) were extremely useful, and his papers are referenced in almost all subsequent papers on the subject.

To be consistent with other studies of shell morphology, our method of measurement is based on Raup’s four factors defining a logarithmically coiled shell. However, Raup’s method required that the shell be opened along the coiling axis to get clear measurements of the axis and the generating curve. In our case, all measurements had to be non-destructive. Photographic data were collected on shells from the ANSPs in Philadelphia, Pennsylvania. Photographs of each shell were taken; the four views of the shells are: perpendicular to the coiling axis towards the protoconch (dorsal); the coiling axis from the umbilicus (basal); parallel to the coiling axis on the side of the last whorl (abapertural); and in the same plane as the face of the aperture (aperture). The same metrics will be made on photographs of the shells in WestLand’s collection.

Raup’s four basic parameters are:

1. The whorl expansion rate ($W$)
2. The rate of whorl transition ($T$)
3. The shape of the generating curve ($S$)
4. The position of the generating curve relative to the coiling axis ($D$).

These four unitless parameters define the shape of a shell but not the size. One more measurement, such as the maximum diameter is needed to define the size and shape. Also, Raup’s parameters are only valid from the end of the protoconch to the point at which the rate of whorl transition ($T$) increases as the shell approaches maturity. Measurements from the protoconch suture and the maturing section of the suture are also collected, but are not used to calculate any of Raup’s parameters.

Figure 4 shows the abapertural view and the measurements used to calculate the whorl transition rate ($T$) and the generating Curve ($S$). Figure 4a shows the calculation of the location and direction of the coiling axis, and the enveloping angle ($β$) which is directly related to the whorl transition rate ($T$).

Figure 4b shows the points used to calculate the generating curve ($S$). It appears that an ellipse closely fits the generating curve. The green ellipse is used as a starting point in the numerical program that finds a best-fit
ellipse by maximizing the coefficient of determination of a least-squares fit. The red ellipse is the result of the calculation. Figure 4c shows the record copy of the abapertural view with all measurements.

Figure 5 shows the dorsal view and the measurements used to calculate the whorl expansion rate ($W$) and the maximum diameter. Figure 5a shows the points along the suture used to calculate $W$. The points start after the protoconch and are taken every 30 degrees along the suture until the whorl transition rate noticeably increases. The whorl expansion rate ($W$) is found by maximizing the coefficient of determination of a least-squares fit of the points along the suture. The algorithm also finds the coiling axis and corrects for any angle in the coiling axis relative to the focal plane. Figure 5b shows the record copy of the dorsal view with all measurements including the maximum diameter.

Figure 6 shows the record copy of the basal view with all measurements. The position of the generating curve relative to the coiling axis ($D$) is the ratio of the radius of the umbilicus to the distance to the outside edge opposite the aperture.

Remaining work includes completion of measurements of the ANSP photographs, photographs and measurements of WestLand’s 2008 and 2009 specimens, an analysis of the distribution of values of each of the parameters measured, and a statistical analysis of the multi-dimensional data.

The genitalia of the live snails at WestLand, once sacrificed, will be photographed and described. The information on the morphology of the genitalia will not be shared with the staff analyzing the shells until the statistical analyses of the shells are complete.

4. REFERENCES


ROSEMONT PROJECT
Talus Snail Study
Vicinity Map
Figure 1
PHOTO 1. Large-shelled talussnail.

PHOTO 2. Talus slopes inside the Rosemont project area.
PHOTO 3. *Sonorella* habitat with view along edge of talus. Talus edge is relatively stable with lichens covering rocks and shrubs along the talus edge. Center of talus slope is unstable with areas of rocks without lichens.

PHOTO 4. Fungus growing on rocks buried within a humid talus slope.
APPENDIX B

COPY OF PAGE FROM FERRISS TO PILSBRY
Stations 1917-18, P2

(N.B. Stations, Arizona, from 13 to 45 inclusive, see another list, "Santa Catalina, Galluro and Tortillita ranges--J.H.F.")

Silver Bell range
Sta. 46-Slides quartzite hill N.E. mine headquarters.

Sierrita range.

√ Sta. 47-Largest Cn. N.E. bank of gulch and in the rock slides above Rosemont, Santa Ritas.

Sta. 48-Slides near tunnels S. of camp, small Son. all dead.
Sta. 49-In saddle above 48, E. side, larger Son., small also.
Sta. 50-W. side of saddle, overlooking Helvetia, 3 alive, Son.
Sta. 51-Large slide below 50.

√ Greater - Sta. 52-Four miles S. near placer mine, (lime ridge west of mine) ville.

TUCSON RANGE Dec. 25, 1917.
√ Sta. 53- Bones of Son. N.W. of Pictured Rocks I-2 M.

2 yd. 54-About 4 M. N. of 53, W. side of range, one of several slides facing W. next Mt. north.

2 yd. 56-Same mountain, slide facing south.
(N.B. Sta 54 and 56 dumped together by mistake, J.H.F.)

1/4 57-Table mountain I-2 M. east of 54.

23, 1918

2 yd. 58-About 3 W. of Pictured Rocks, opposite Yuma mine.

(S Mountain Sheep camp.)

2 yd. 59-About 5 M. No. of Sheep camp in quartzite outltier west of the range, and a twin outlier, of lime 60-Half a mile above sta. 58, both porphyry slides.

SI 81-Slide westward of 60 across the gulch, and higher.

63-Thys. horni abd Bifid tuba, old miners camp foot of hill containing Sta. 58, 60, 61.

(Wild Pig Camp) 63-About 3 M. So. of Silver Bell road, Nelson Ranch, So. side amphitheater, small slide point of Mt. So. W. point of the amphitheater.

2 yd. 64-No. slope of same in gulch boulders foot of peak.

65-Bed of dry wash, below above, small stuff.

66-Near top of range, above 64.

67-Over the range, facing the flat-topped mountain.

68-Short distance farther west than 67.