

These are transcriptions of typewritten manuscripts which, though unsigned, are undoubtedly by F. W. McNair. The originals can be found in the James Fisher Collection, at the Michigan Technological University (MTU) Archives and Copper Country Historical Collection, on the campus of MTU. The first article appeared, with minor changes, in the Mining and Scientific Press, 14 July 1906. The second, which is undated and includes handwritten corrections, may be an earlier draft and/or notes for McNair's earlier talk to the AAAS, the abstract of which appears in Science XXIII, 415-416 (1906).

FALLING BODIES IN THE DEEP VERTICAL SHAFTS OF THE LAKE SUPERIOR COPPER DISTRICT

The mystery of the dark has always hung over caverns, whether of nature's excavation or of the digging of venturesome man. Especially is this so as they attain great extent or great depth. Instinctively one feels that in a very deep shaft or very far underground conditions must be quite different from those one finds on the surface, and, perhaps because of the one obvious and striking difference due to the absence of light, there is a tendency to credit the uncanny. When, therefore, there is made the statement that objects dropped into the deep shafts of the Lake Superior copper district "do not fall to the bottom but are invariably found clinging to the east side of the shaft" probably the average reader is apt to credit the statement as noting one more of the strange and uncanny facts which belong to the underworld without any serious attempt to inquire what may be the truth of the matter. When the press correspondent in telling it adds a touch of the gruesome in the implication that among the objects frequently found "clinging to the east side of the shaft" are the pieces of a dismembered human body one may suppose that reportorial skill has reached its acme, and that there has been produced a real gem of a newspaper "story". Such a story was put forth not long ago by an enterprising correspondent and was copied in the daily press throughout the length and breadth of the country. One may question whether a plain statement of the truth could obtain more than a fraction of the same extent of circulation.

Yet the truth, though it contains of course nothing of the supernatural and little indeed of the unfamiliar, is nevertheless sufficiently interesting to make it worth while to narrate the facts behind the statement that objects dropped into the deep vertical shafts do not fall to the bottom.

To begin with this statement in itself is much more nearly exact than the thoughtful person would at first be inclined to believe. Very rarely, to say the least, do objects falling from the collar reach the bottom of the shaft, nor, indeed any where near it. On investigation this fact is not so very surprising nor are most of the reasons for it so far to seek. The vertical shafts of the Lake Superior copper district are very deep, some of them the deepest in the world. Further in proportion to their depth they are of very small cross section. The common impression seems to be in contradiction to this last statement, and at first sight when we learn that a shaft like number five of the Tamarack mine is nine by thirty feet in cross section, its horizontal dimensions seem little short of colossal. But if it is noted that at five thousand feet the shaft is over five hundred times as deep as wide the horizontal dimensions begin to look small in proportion.

Moreover it must be remembered that the shaft is divided by the timbering throughout its depth into compartments, the larger of which are roughly five by seven feet. (Foot note. See Copper Mines of Lake Superior; T. A. Rickard, p. 93). Really then in the deepest shafts the separate compartments form tubes over seven hundred times as deep as the greater horizontal measurement and over one thousand times as deep as the smaller dimension. In proportion they do not differ greatly from the tube of the ordinary chemical thermometer. My experience is that

few persons even among those somewhat familiar with such shafts realize or comprehend these proportions. This undoubtedly results because to a person in it so little of the length of the shaft is visible at one time. Taking into account the relatively extreme smallness of cross section, it is easy to see that an object falling into the shaft must follow a straight line very close to exactly parallel with the axis of the compartment if it is not to hit a wall in its downward course.

If the walls were smooth the object might strike many times, and, simply rebounding, keep on its downward course. But in a shaft timbered in the ordinary manner, striking the walls means a lodgement sooner or later and consequent interruption of the fall. In the Tamarack number five shaft the length of the set from center to center is six feet. (Foot note. See Paper by W. M. Parnall on "No. 5 Shaft at the Tamarack Mine", Proceedings Lake Superior Mining Institute, 1901). Back of these timbers is either irregular rock surface or the irregular surface of the lagging. There are, therefore, more than eight hundred opportunities for an object striking an outside wall on its way down to find lodgment.

Were there no air present a body would require better than seventeen and a half seconds to fall five thousand feet. The air in the shaft, mostly denser than at surface, of course increases the time occupied in descent. Under such conditions it is clear that the horizontal velocity permissible if the body is to reach the bottom is small indeed. Less than one half a foot per second would carry it clear across the longer horizontal dimension while it was falling. Objects falling into the shaft under ordinary conditions nearly always start with some horizontal velocity, indeed it is usually due to such initial velocity in the horizontal that they get into the shaft at all.

Almost all common objects are irregular in shape, and, drop one of them ever so carefully, contact with the air through which it is passing soon deviates it from the vertical, giving it a horizontal velocity, and this when the air is quite still. The object slides one way or another on the air it compresses in front of it. Even if the body is a sphere, the air will cause it to deviate, if it is rotating about an axis out of the vertical. Again the air in the shaft is in ceaseless motion, and any obliquity of the currents would obviously deviate the falling body from the vertical no matter its shape.

If the falling object is of iron or steel the magnetic influences of the air and steam mains which pass down the shaft, and which invariably become strongly magnetic may cause it to swerve from a vertical course.

The hindrances to describing a vertical path so far considered are well within familiarity for the person of average information, but there is another cause of deviation whose action is not so familiar, and which yet operates to carry our body to one side, always in a definite direction. The cause itself is familiar enough, being nothing other than the diurnal rotation of the earth on its axis. Because of this rotation a body dropped from a fixed position or projected vertically downward will, if then left entirely to itself, bring up always to the eastward of the vertical along which it would otherwise fall. It might seem at first thought as if the body should depart from the vertical to the westward rather than to the eastward since the earth rotates in the latter direction. However the so-called fixed position is fixed only with reference to the earth's surface, and the object before release partakes of the same motion, and has the same velocity, as all other "fixed" objects in its neighborhood. Were it at the equator this speed would be say thousand miles per hour. The speed grown less toward the poles, where it becomes nothing. In fact the object is traveling in the circumference of the circle of latitude in which it happens to lie. Points beneath it have a speed which is smaller as the (*sic*) lie nearer the axis of rotation. The freely falling body retains the eastward speed with which it started, and so gains on the slower moving

parts of the earth which it is approaching. It, therefore, moves eastward from the vertical in which its fall began. The reader who in his study of physical geography worked over the reason of the easterly or westerly deviation of the trade winds was considering an exactly similar set of conditions.

This easterly deviation was pointed out by Newton over two centuries ago, who stated in the quaint language of the day that the falling body “will not descend the perpendicular....., but outrunning the parts of the earth will shoot forward to the east side of the perpendicular.....”. (Foot note. See quotation in interesting article by Prof. E. H. Hall, *Physical Review*, vol. XVII, p. 180, September 1903). It has therefore been a fact well known to physicists for a long time.

During investigation of the cause of the divergence of long plumb lines hung in number five shaft of the Tamarack mine (Foot note. See *Electrical World*, April 26, 1902, also *Science*, June 20, 1902, or *Terrestrial Magnetism*, September 1902) some of the mining people called attention to “the old Cornish method” of plumbing a shaft by dropping a suitable object like a spherical shot from a determined point of suspension at the collar of the shaft and receiving it in a prepared bed of clay at the bottom, the vertical being then assumed as the line joining the point of suspension with the center of the depression made in the clay. This suggestion led those engaged in the investigation to discuss the amount of easterly deviation which would be observed if a sphere were dropped forty-two hundred feet, the length of the plumb line then under observation. A rough calculation by one of the party gave something like four feet. A deviation which could be consistently measured in feet excited great interest and every one concerned expressed a desire to witness a trial by experiment of so striking a demonstration of the earth’s diurnal rotation.

Accordingly at the end of a certain day’s plumbing operations a steel sphere, chosen because it was the only convenient object at hand, was suspended about one foot from the timbers near the western corner of the compartment. The compartment stands diagonally with reference to the cardinal points. Forty-two hundred feet below a clay bed was placed, having its eastern edge some five feet east of the point of suspension of the ball. When the ball appeared to be still the suspending thread was burned, and the instant of the dropping of the ball was indicated by a prearranged signal transmitted by telephone to the observers below, who, watch in hand, waited for the sphere to strike the bed of clay. It failed to appear at all. Another like sphere was hung in the center of the compartment and the trial was repeated, with the same result. The shaft had to be cleared and no more trials were feasible. Some months after, one of the spheres, presumably the latter one, was found by a timberman where it had lodged in the timbers eight hundred feet from surface.

It is, however, not probably that these balls lodged because of the earth’s rotation alone. The rough calculation mentioned above gave too large a figure for the deviation. The matter is really more complicated than the foregoing discussion implies. It has received mathematical treatment from the great Gauss. According to his results, the deviation to the east for a fall of five thousand feet at the Tamarack mine should be a little under three feet. Both spheres had that much to spare before striking the timbers. It is almost certain, therefore that others of the causes mentioned in the beginning acted to prevent a vertical fall. At any rate these trials serve to emphasize the unlikelihood that an object which falls into a deep vertical shaft, like those at the Tamarack mine, will reach the bottom, even when some care is taken in selecting it and also to start it vertically. No account of the trials was published because they lacked serious purpose too much and were too crude to be dignified as real experiments, but they excited great interest among the people about the mine and talk about them spread until it finally gave foundation for the exaggerated press story of objects “clinging to the east side of the shaft”.

If the timbering permits lodgment, as is the case in most shafts, it may truthfully be said

that if a shaft is deep in proportion to its cross section few indeed will be the objects falling into it which will reach the bottom, and such objects are more likely to lodge on the easterly side than any other.

Michigan College of Mines,
June 1, 1906.

Undated typewritten Draft with handwritten corrections:

From New York to San Francisco this article has been persistently circulated. Probably it would be very difficult to circulate a hundredth part as widely the modicum of truth therein contained. So long as the story was confined to the daily press I did not deem it necessary to take notice but since it has begun to appear in technical and scientific journals, and, as my correspondence bears evidence, is attracting the attention of scientific men it seems best to put forth an account of the facts.

In September 1901 two very long plumb lines were hung in No. 5 shaft of the Tamarack Mine. They were the longest recorded up to that time. In working with them it was discovered that their distance apart was about one tenth of a foot greater at the bottom than at the point of suspension 4250 feet above. I have elsewhere given an account of these circumstances and of the rather elaborate investigation of the cause of the divergence which was finally traced to currents of air circulating in the mine.

During this investigation it was given as the opinion of some of the people at the mine, needless to say they were not on the engineering staff, that after all the best method of plumbing a shaft was the old Cornish one of dropping a spherical shot from a marked point at the mouth, and receiving it on a bed of clay at the bottom. The vertical was then assumed to be the straight line between two points, one the point of suspension and the other the center of the depression in the clay made by the shot. It is of interest to know that this method was recently used to plumb a shaft in which it was difficult to hang a plumb-line.

The proposition of this method for the case of a deep shaft caused some amusement on the part of my helpers, and there ensued a lively discussion among us as to the amount of easterly deviation which would be exhibited if we were to drop a sphere through the distance from the collar of this shaft to the 29th plat a distance from the surface 50 ft less than the length of the plumb-line with which we were dealing and also as to the possibility of the rotation of the earth in any way influencing the relative position of the two lines. The easterly deviation which might be expected was very roughly figured by one of us during the conversation and was announced as something like four feet. The whole subject was in a way new to each of us and a derivation which could be measured consistently in feet seemed impressive. We were correspondingly interested and a desire was expressed by several to witness so striking a demonstration of the rotation of the earth.

I shared this desire fully as much as any one of my assistants and we soon had a rough scheme arranged for the experiment. It was planned to hang a smooth steel sphere two inches in diameter on a thread at a point whose azimuth and distance from a plumb-line were known. When the sphere was as quiet as it was possible to get it the thread was to be burned and the ball

was to be received below in a clay bed properly placed. The steel sphere was chosen because it happened to be at hand in the form of some very truly spherical balls used in our physics laboratory in simple pendulum experiments. A box of clay some three feet square and four inches deep was prepared and placed on a collar in the shaft at the 29th plat to which the plumb-lines were hung. This clay bed extended extended (sic) some five feet or more to the east of the position of suspension of the ball. The ball was suspended a foot or two above the collar in the shaft house which covered the shaft and cut off surface air currents. A telephone line had been placed in the shaft and was available for signalling (sic). It had been figured that, neglecting the air, the sphere would require a little over sixteen seconds to reach the plat.

At the instant the thread was burned a signal was sent across the telephone to warn those below that they might know when to expect the arrival of the sphere. A person stood at the telephone, watch in hand, noted the time of the signal from above and warned those watching by counting aloud the seconds. We were surprised when the ball failed to appear at all. Our computation had been rough, the whole experiment was crude, the air resistance had been neglected but as we had at least a foot to spare in (unreadable correction) We certainly did expect the ball to get 4200 feet from surface.

Some of the mine employes (sic) who were with us insisted that the ball should have been hung in the center of the compartment, that because of the unequal air resistance due to nearness to one corner it had been drawn into the timbers. Our own theory was that our calculation was probably too rough and that the resistance of the air cut a much larger figure than we had guessed it would. Nevertheless, as these employes requested that a trial be made with another ball hung in the center, we so placed one and of course were not surprised when it did not appear at the 29th plat. A month or so after one of the spheres was found about 800 feet from surface; it had lodged in the timbers at the side of the shaft.

If the extreme crudity which marked the experiment is condemned I have only to reply that the whole matter was interjected into the work on hand, that it was almost wholly irrelevant, and the experiment was entered upon solely to gratify our desire to experience in our own sensations a striking demonstration of the diurnal rotation. In reality it was not an experiment at all, there being no serious purpose behind it. Therefore, it is not mentioned in either of my accounts of the investigation of the divergence of the plumb-lines, nor have I or any of my assistants in that work ever heretofore published a line concerning it. True, it interested us in the matter of the easterly deviation of falling bodies in a way in which we had not previously been interested. In considering investigations undertaken by me later with the help of the U.S. Coast and Geodetic Survey on the variation of gravity beneath the surface of the earth there appeared to me to be a possibly demonstrable connection between the curve followed by a body falling beneath the surface, and the distribution of the earth's density. There is certainly some relation existing between the two and it is conceivable that if the path of the falling body were accurately mapped it might yield otherwise unattainable information as to the distribution of the earth's matter.

But although nothing was published the fact that the balls did not drop to the bottom of the shaft excited great interest among the employes of the mine and conversation about it gradually spread until it was pretty generally known in the Copper Country. The local papers mentioning it. The first reference outside so far as I am aware was made quite without the knowledge of the participants in the experiment in a paper read before the Western Society of Engineers at a meeting in Chicago. This paper was afterward published. While some of its statements were correct it gave a very wrong impression of the surroundings of the experiment (sic) and of its object. Gradually the story grew until there resulted the absurd article to which I have referred in the beginning. To any one familiar with the conditions about a deep shaft the

absurdities are obvious and harmless and it is with amusement that they read of objects whether monkey wrenches or pieces of human anatomy being “invariably found clinging to the east side of the shaft”, while any physicist will undoubtedly be entertained by the statement that a marble hung on the end of a thread was absolutely still.

The appearance of the paper read before the engineering society had determined me to give a brief account of the experiment before Section D at the St. Louis meeting of the American Association but I discovered that President R. S. Woodward was engaged in reinvestigating the theory of a curve followed by a falling body and I determined to say nothing about the matter for the time being, hoping to present when it was mentioned some plan of experiment to be followed with the purpose of verifying his results. So far other things have claimed his time but it is to be hoped that his theory may soon be put forth, when if it is considered worth while to undertake a verification undoubtedly as good an opportunity as the world affords is to be found in the deep shafts of the Lake Superior copper district.

The paper read before the engineering society was undoubtedly:

“Copper Mining in Upper Michigan,” J. F. Jackson, Journal of the Western Society of Engineers, Vol. VIII, No. 1, February 1903, pages 1-19; with discussion on pages 19-21. Mention is made of McNair’s Tamarack Mine experiments on pages 10 and 11. The presentation was at the regular meeting on 3 December 1902 (see the same journal, Vol. VII, 1902, page 670).