When Is A Rod Not 16.5 Feet?[1]

(More times than not)

by

Knud E. Hermansen[2]
Ph.D., P.L.S., P.E., Esq.

> The science of geometry and mathematics is exact. The infinite depths of stellar space are measured with such exact nicety that the position of stars and planets can be calculated to the fraction of a second of time ... How can it be that in the ascertainment of one line of so small an area, bounded by four lines only, a difference of from 8 to 24 feet arises? It is evident that the methods pursued, and not a defective science, have brought about the different results, different maps." *Warren v. Boggs*, 90 W.Va. 329, 332, 111 S.E. 331 (1922)

As experienced title attorneys and paralegals know, measurements along the same boundary vary between old and new surveys. At first impression there does not seem to be a logical reason for the sometimes large disparity between the measurements found in the deed and the modern surveyor's measurements. Consequently, litigators and the surveyor's client have the impression that the surveyor is at worst incompetent or at best negligent in surveying the historical boundaries -- adding or taking away land. The fact is that most times differences in the measurements do not reflect any change in boundary location or the addition or loss of land. Variations between old and new measurements are in fact common and should raise questions only if there were no differences.[3] Nevertheless, clients and litigation involving property boundaries frequently require a rational explanation to help explain the difference between the measurements cited in the records and more recent measurements.

> The science of mathematics is exact, but the different results reached in its application by different surveyors, is sometimes startling to the layman, when applied to what appears to be an ordinary survey." *Zirkle v. Three Forks Coal Company*, 103 W.Va. 614, 626, 138 S.E. 371 (1927) quoted from, *Warren v. Boggs*, 90 W.Va. 330 (1922)

> The original surveys of lands in the older States of the American Union, were

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2 Knud Hermansen has a Ph.D. in civil engineering from the Pennsylvania State University and a J.D. from West Virginia University. Currently, he practices law, surveying, and engineering in Old Town, Maine and is an associate professor in civil engineering technology and surveying engineering at the University of Maine.

3 *Western Mining & Manufacturing Company v. Peytona Cannel Coal Company*, 8 W.Va. 406, 431 (1875)

> exceedingly deficient in precision.This arose from two principal causes; the small value of land at the period of these surveys, and the want of skill in the surveyors. The effect at the present day is frequent dissatisfaction and litigation. Lots sometimes contain more acres than they were sold for, and sometimes less. Lines which are straight in the deed, and on the map, are found to be crooked on the ground. The recorded surveys of two adjoining farms often make one overlap the other, or leave a gore between them. The most difficult and delicate duty of the land-surveyor, is to run out the old boundary lines.... Gillespie LL.D., Civ. Eng., W.M. *Treatise on Land-Surveying Comprising The Theory Developed from Five Elementary Principles; and The Practice with the Chain Alone, The Compass, The Transit, The Theodolite, The Plane Table, & c.*: D. Appleton and Company, New York (1881)

To comprehend the basis for the difference, knowledge of the surveyor's duty and some historical information is required. The surveyor's duty in regard to surveying historical boundaries is often described as "following in the footsteps of the original surveyor."[4] Unfortunately, searching for footsteps involves searching for recollections, markings, monuments, and records that typically range in age from 50 to 300 years old. The intervening time has taken its toll on this evidence through decay, fire, flooding, construction, unintentional destruction, deceit, ignorance, and the unavailability or incompetency of reliable witnesses, to name a few.[5]

> [B]ut old surveys are not to be so tested. Most perfect in the beginning they are constantly undergoing change and decay, until by wind, fire, rottenness, and the acts and frauds of men, their evidences lie only in memory and hearsay." *Kennedy v. Lubold*, 88 Pa. 246 (1878)

> Monuments referred to in deeds are often perishable; as trees, wooden buildings, or fences; or slight and temporary; as a stake, or a stake and a few loose stones, intended to be supplied by something of a more permanent character. They serve to point out at the time, to the parties in interest, the bounds of the land conveyed. After these monuments are gone, and such a period of time has elapsed, that no one can be found who remembers to have seen them, or can testify as to their location; uniform continued occupancy, by buildings, fences or other equivalent indications of ownership is evidence that the land was located according to the original monuments. These monuments perish; and time sweeps away those who could point out where they stood...." *Cutts v. King*, 5 Me. 482, 487 (1829)

To further compound the problem, preventative or curative actions

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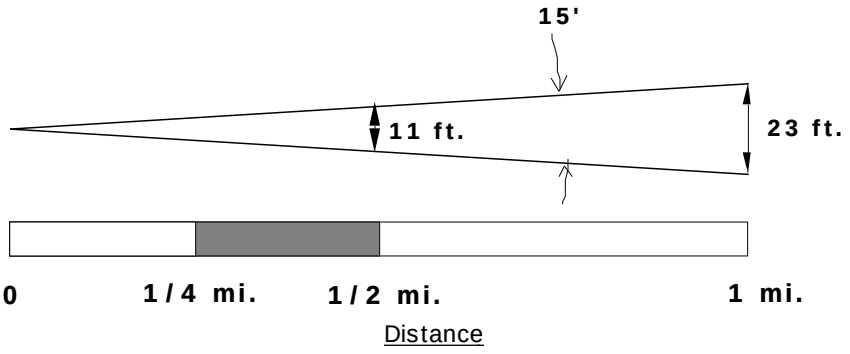
4 *Rivers v. Lozeau*, 539 So.2d 1147 (Fla: 1989) While the concept has always been applied, the words that so aptly describe the surveyor's charge are said to have first appeared in a talk titled: "The Judicial Functions of Surveyors," by Chief Justice Cooley of the Michigan Supreme Court, read before the Michigan Association of Engineers and Surveyors.

were prevented through ignorance, denial, or the seemingly prohibitive costs associated with surveying. As a result, the deed descriptions so often copied for one conveyance to the next are seldom as reliable or unpretentious as reliant parties would hope. The following is a brief explanation for some of the many errors and inaccuracies in older measurements.

Equipment Precision: The equipment used during the early surveys was not as refined or precise as modern survey equipment.[6] The typical equipment used in early land surveys consisted of a compass and chain. In some rural areas this equipment continued to be employed up into the 1960's.[7] The typical compass and chain[8] was seldom able to obtain measurements better than the nearest 1/4 degree (15 minutes) in direction and nearest link (7.92 inches) in distance.[9]



Angular Uncertainty	16,500 ft. (1000 rods)	5,280 ft.	1,650 ft. (100 rods)	1,000 ft.	500 ft.	165 ft. (10 rods)
10°	2887.1	923.9	288.7	175.0	87.5	28.9
1°	288.0	92.2	28.8	**17.5****	8.7	2.9
30'	144.0	46.1	14.4	8.7	4.4	1.4
15'	72.0	**23.0***	7.2	4.4	2.2	0.7

5 *Ulman v. Clark*, 100 F. 180, 187 (W.V. 1900), *Northumberland Coal Company v. Clement*, 95 Pa. 126 (1880), *Kennedy v. Lubold*, 88 Pa. 246 (1878), *Ralston v. Groff*, 55 Pa. 276 (1867), and *Cutts v. King*, 5 Me. 482, 487 (1829)

6 *Winding Gulf Colliery Co. v. Campbell*, 72 W.Va. 449, 467-468 (1913)

7 In fact, it would not be unusual to see this method employed at the present time for some large, rural woodland parcels.

8 "The ordinary surveyor's chain is sixty-six feet, or four poles long, composed of one hundred links, each connected to the other by two rings, and furnished with tally marks at the end of every ten links." W & L.E., *A Manual of the Principal Instruments Used in American Engineering and Surveying*, W & L.E. Gurley, Troy, N.Y. (1878) p. 141

9 A "finer cut" was impractical since traverse tables were generally limited to the nearest 15 minutes. *The Theodolite, The Plane Table, & c.*: D. Appleton and Company, New York (1881), Gurley, W & L.E., *A Manual of the Principal Instruments Used in American Engineering and Surveying*, W & L.E. Gurley, Troy, N.Y. (1878)

1'	4.8	1.5	0.5	0.3	0.1	0.0
30"	2.4	0.8	0.2	0.1	0.1	0.0
15"	1.2	0.4	0.1	0.1	0.0	0.0
1"	0.1	0.0	0.0	0.0	0.0	0.0

The error caused by a 15 minute deviation in direction is shown by the figure. A 15 minute deviation in direction results in an error of 23 feet per mile.* Similarly, a 1 degree deviation in 1000 feet results in an error of 17.5 feet.**

Figure 1

The typical compass did not have magnification and only a rudimentary method to measure the slope (if at all). The limitations of the compass were well known among the early surveyors and members of the Bar.[10] The magnetized needle frequently lost its magnetism or was subject to changes in the magnetic pole or variances caused by electric storms, the Aurora Borealis, and nearby magnetic attractions (local attractions).[11] In some cases, metal shavings or impurities were found to reside in the brass compass housing that drew the needle off along certain directions.[12]

The chain, the other piece of ancient survey equipment, was heavy and unwieldy. It was difficult to suspend without introducing considerable sag. Links soon stretched, became bent, clogged with debris, or kinked adding to the uncertainty of measurements.[13]

The adoption of the vernier transit and much lighter steel tape by many surveyors in the late 1800's and early 1900's allowed practitioners to measure directions to the nearest minute and distances to the nearest 1/100th of a foot, every 100 feet.

10 *Lodge v. Barnett*, 46 Pa. 477 (1864), *Hagey v. Detweiler*, 35 Pa. 409 (1860), *Lodge v. Barnett*, 46 Pa. 477 (1864), *Ralston v. Groff*, 55 Pa. 276 (1867), and *Blasdell v. Bissell*, 6 Pa. 258 (1847)

11 *Variations of the Magnetic Needle, Report of the Commissioner on the Variations of the Magnetic Needle*, State of Maine, 1866.

12 *Cox v. Couch*, 8 Pa. 147 (1848), Gurley, W & L.E., *A Manual of the Principal Instruments Used in American Engineering and Surveying*, W & L.E. Gurley, Troy, N.Y. (1878)

13 *Lodge v. Barnett*, 46 Pa. 477 (1864), *Heaton v. Hodges*, 14 Me. 66 (1836), W & L.E., *A Manual of the Principal Instruments Used in American Engineering and Surveying*, W & L.E. Gurley, Troy, N.Y. (1878), "If a chain's long links are held together by three rings, which was common enough, then there are eight wearing surfaces per link or 800 wearing surfaces per chain. If each surface wore 0.01 inch, the chain would be eight inches longer." Tascano, Patrick "Gunter's Chain" *Surveying and Land Information Systems*, Vol. 51, No. 3, p 155 (September 1991)

(Compare this to modern equipment which can consistently measure angles to the nearest second and a distance (as far as visibility permits) to the nearest hundredth of a foot. Using the newest equipment, satellite receivers, visibility between stations is no longer a factor.)

Practitioners: The training and skill of some past practitioners left much to be desired.[14] Rigorous training and formal education for surveyors were haphazard or nonexistent. One or more surveyors seemed to practice in every locale where their only attributes seem to have been a sense of direction, hemp rope or consistent pace, and a passable talent to draw lines. Their practice was questionable and would amount to fraud by today's standards.[15] Licensing, which was intended to remove the charlatans, was not mandatory in many states until the later half of the 1900s.[16] Even after licensing of surveyors, many licensing requirements did not require a test or proof of skills before issuing a license to practice.

Assuming the surveyor had the minimum skill and knowledge, the help the surveyor employed seldom did.[17] The surveyor arriving at the site with a trained or semi-trained field crew was almost unheard of in the past. Help was more often then not the client and men hired from the local population. A survey crew in the early days was supervised by the surveyor or a trusted deputy who generally operated the compass or transit. The remainder of the survey crew (on a large survey) consisted of two chainmen hired from among the local population, two or more axemen to cut and mark line, a cook, and a cook's helper to clean utensils and help pack supplies. Training of the chainmen was rudimentary at best and left much to be desired in the resulting accuracy of the

14 Many practitioners will candidly admit that the early surveyors in George Washington's time were of the highest caliber. The skill and knowledge of the average surveyor subsequently went downhill. The trend appared to reverse at some point midway in this century. See e.g. *Mahon v. Duncan*, 13 Pa. 459 (1850)

15 *Blain v. Woods*, 145 W.Va. 297, 306, 115 S.E.2d 88 (1960)

16 The first licensing act was attributed to Wyoming in 1907. Biship, L.C. *Surveying in Wyoming During Territorial Days and Now* (1957)

17 *Ralston v. Groff*, 55 Pa. 276 (1867), *Cox v. Couch*, 8 Pa. 147 (1848), and *Blasdell v. Bissell*, 6 Pa. 258 (1847)

distances.[18]

> [I]t was not error for the court to call the attention of the jury to the fact that defendant's measurements were made by a 'baker attended by a tinsmith under the supervision of a lawyer.' This is not such departure from judicial gravity as to call for a reversal. *Omenstetter v. Kemper*, 6 Pa.Super. 309 (1898)

Terrain and Site Conditions: Present day practitioners and landowners sometimes fail to remember what the terrain and site conditions were like at the time of the early surveys. Virgin timber several feet in diameter, both standing and fallen, presented formidable obstacles to thwart the surveyor in measuring a straight line through the forest.[19] Hostile Indians,[20] foreign powers seeking control of the wilderness, squatters not interested in paper title, wild animals, disease, and lack of shelter and nutritious food took their toll. Under the circumstances, surveyors were more concerned with their surroundings and well being than their measurements.

> The difficulty of making an accurate survey by courses and distances, under the conditions obtaining in that country at the time this survey was made, were very great. It was a rough heavily timbered country, making it hard to see between stations, distant from each other, and slow and irksome to chain directly from station to station; but it was comparatively easy to select accessible points for corners, and practically guess at the courses and distances. To this we must add the circumstances that there was then a mad rush of speculators into this region for land at two cents an acre, and consequent pressure upon the surveyors, well calculated to induce resort to the easiest and quickest method of achieving results." *State v. King*, 64 W.Va. 546, 579-580 (1908)

> [I]n the wilderness in which those early surveys were made, it was practically impossible to avoid mistakes. *Winding Gulf Colliery Co. v. Campbell*, 72 W.Va. 449, 471 (1913)

Even after the virgin timber was removed and the land settled, the surveyor's ability to measure accurately was hampered by dense growth brought on by the now abundant sunlight and rich soil on what had once been shaded forest floor. Blazes once made to mark the boundaries were lost when the timber was removed or decayed. The present twenty minute drive to the courthouse took a day or

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18 *Reilly v. Mountain Coal Co.*, 204 Pa. 270, 54 A. 29 (1903), *Omenstetter v. Kemper*, 6 Pa.Super. 309 (1898), *Fisher v. Kaufman*, 170 Pa. St. 444, 33 A. 137 (1895)

19 *Gwynn v. Schwartz*, 32 W.Va. 487, 492-493 (1889)

20 *Ulman v. Clark*, 100 F. 180, 183 (W.V. 1900)

more in the past on roads were mere muddy paths or covered with snow or debris. As a result, records were not always obtained and the previous measurements for the property and measurements for the adjoining property were not always compared before recording a new description or map.

Land Values: Many attorneys continue to use the same description written a hundred years ago. This practice not only fails to uncover latent problems but ignores the law of economics. The same parcel worth several hundred thousand dollars today was frequently purchased for pennies when the last survey was performed.[21] In the past, the cost of having the land surveyed may have been more then the price to purchase the land. Under these conditions, speed was more important than fastidious measurements.[22] The carelessness that caused the omission or overlap of a few acres at ten cents an acre was not worth the twenty five cents required to resurvey and correct the error. The landowner purchasing 400 acres was not concerned with overlaps or a deficiency of a few acres.[23] Needless to say, a deviation of a rod or two on a measurement would not have caused any concern whatsoever.

Procedures: The procedures employed by early surveyors leave much to be desired by today's standards. Old survey texts are filled with suggestions that were generally unknown or ignored by the early survey practitioner.[24] Surveyors were cautioned that frequent use of the chain would inevitably cause the links to stretch and eventually require the surveyor to remove a link or two. The surveyor willing to achieve measurements accurate to a few feet was advised to avoid measurements using the compass at certain times since the compass needle tended to vary by a few minutes

21 *State v. King*, 64 W.Va. 546, 579-580 (1908) and *Simmons Creek Coal Company v. Doran*, 142 U.S. 417, 432 (1891)

22 *State v. King*, 64 W.Va. 546, 579-580 (1908) and *Ralston v. Groff*, 55 Pa. 276 (1867)

23 *Collins v. Barclay*, 7 Pa. 67 (1847)

24 See e.g., Hosmer, George L, & Charles B. Breed, *The Principles and Practice of Surveying*, 1st Ed., John Wiley & Sons, New York (1906), Gillespie LL.D., Civ. Eng., W.M. *Treatise on Land-Surveying Comprising The Theory Developed from Five Elementary Principles; and The Practice with the Chain Alone, The Compass, The Transit, The*

during these periods of the day.[25] Deviations caused by the shift in magnetic north over time and location were ignored even though the error amounted to several degrees in some cases.[26] Instructions packaged with new compasses were quick to warn the surveyor to hold the chain away from the compass, periodically sharpen and adjust the spindle, and relieve the static electricity that built up in the glass.[27]

> When, however, the glass becomes electric, the fluid may be removed by breathing upon it, or touching different parts of its surface with the moistened finger. An ignorance of this apparently trifling matter has caused many errors and perplexities in the practice of the inexperienced surveyor. Gurley, W & L.E., *A Manual of the Principal Instruments Used in American Engineering and Surveying*, W & L.E. Gurley, Troy, N.Y. (1878)

Problems were so prevalent and generally ignored during surveys conducted in the early and mid-1800's that legislation was passed in many states requiring surveyors to periodically check their chain against a known line and note the deviation of their compass from a known meridian. Even the otherwise cautious surveyor was sometimes unaware of problems caused by iron ore deposits or other localized attractions sufficient to pull the needle off during a reading.

Ignorance of proper procedures or the speed necessary to survey large tracts in a short time resulted in paper surveys (i.e. protracted lines)[28] or surveyors pacing, using stadia,[29] or slope chaining rather than making time consuming horizontal

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Theodolite, The Plane Table, & c.: D. Appleton and Company, New York (1881), Gurley, W & L.E., *A Manual of the Principal Instruments Used in American Engineering and Surveying*, W & L.E. Gurley, Troy, N.Y. (1878)

25 "[O]wing to the influence of the sun, which, in summer, will cause the need to vary from ten to fifteen minutes in a few hours, when exposed to its fullest influence." Gurley, W & L.E., *A Manual of the Principal Instruments Used in American Engineering and Surveying*, W & L.E. Gurley, Troy, N.Y. (1878) p. 57 The diurnal change for Eastport Maine was found to average around 15 minutes. *Variations of the Magnetic Needle, Report of the Commissioner on the Variations of the Magnetic Needle*, State of Maine, p. 17, 1866.

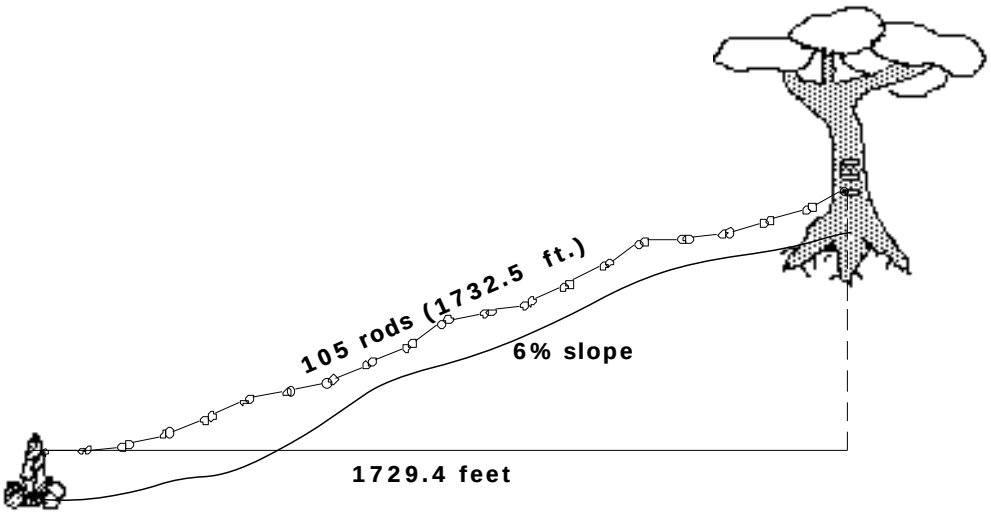
26 *Hagey v. Detweiler*, 35 Pa. 409 (1860)

27 Gurley, W & L.E., *A Manual of the Principal Instruments Used in American Engineering and Surveying*, W & L.E. Gurley, Troy, N.Y. (1878)

28 *West Virginia Pulp & Paper Company v. Dodrill*, 221 F. 780, 785 (N.D.W.Va. 1915), *Ruffner's Heirs v. Hill*, 31 W.Va. 428, 432 (1888), *Packer v. Schrader Mining & Manufacturing Co.*, 97 Pa. 379 (1881), and *Fisher v. Kaufman*, 170 Pa. St. 444, 33 A. 137 (1895)

29 *Keta Gas & Oil Co. v. Jents*, 380 Pa. 217, 110 A.2d 369 (1955)

measurements.[30]



The error resulting from measuring on the slope rather than a horizontal distance is shown in the above figure. At a 6% slope and distance of 105 rods, a three foot error will occur. The steeper the slope or the longer the distance, the greater the error.

Figure 2

In some cases distances were estimated and directions approximated.[31] In other cases haphazard corrections such as adding "one rod to each score" for slope measurements were applied in an attempt to compensate for crude practices.[32]

> [I]t appeared, that at the time this survey was made, an excess of ten or twelve per cent had been allowed by the surveyors in other parts of the lines of said township.... *Heaton v. Hodges*, 14 Me. 66, 67 (1836)

> But the experience of the Courts has shown, that excess of admeasurement is so uniformly indicated in surveys of that early period, the Court is not prepared to say, that the excess, which was proved in this case, was evidence, which would warrant the jury in drawing an inference of fraud. *Machias v. Whitney*, 16 Me. 343, 348 (1839)

The practice of actually running the boundary rather than traversing around the property forced many early surveyors to measure across obstacles or estimate the breadth of the obstacle

30 "[A]ll of the measurements were made in slope feet rather than horizontal feet...." *Vandetta v. Yanero*, 157 W.Va. 220, 222, 200 S.E.2d 674 (1973), *Keta Gas & Oil Co. v. Jents*, 380 Pa. 217, 110 A.2d 369 (1955), *Cox v. Couch*, 8 Pa. 147 (1848) and *Blasdell v. Bissell*, 6 Pa. 258 (1847)

31 *State v. King*, 64 W.Va. 546, 579-580 (1908) and *Fisher v. Kaufman*, 170 Pa. St. 444, 33 A. 137 (1895)

rather than go around it. As a result, estimations were frequent. At other times chains were laid on top of obstacles or the chain curved around the obstacle rather than measuring the straight line distance between them.

Area which is a product of the direction and distances, can be no better than the worst measurement. As a result, the area which is frequently of most concern to the layman is subject to the widest variations and exageration.[33]

> The acre of that day, as is and was well known, in the locations made in this State, was larger than the exact acre. *Bussey v. Grant*, 20 Me. 281, 286 (1841)

Blunders: In the past, just as today, surveyors were prone to make mistakes. Early cases document many blunders that were discovered sometime after the survey.[34] It was not uncommon for the surveyor to lose their tally (the count of the number of chain lengths), transpose numbers, deviate from a straight line, misread the compass and chain, or make a miscalculation.[35]

> [O]ld surveys were often inaccurate; and mistakes often made, in copying their descriptions into the patents; leaving out lines and putting north for south, and east for west; and in copying those descriptions into subsequent conveyances.... *Winding Gulf Colliery Co. v. Campbell*, 72 W.Va. 449, 467-468 (1913)

In some ways, errors were more likely to occur in the past than today. The literacy of the population in the early days led to many errors traceable to poor grammar, lack of formal education, and spelling.[36]

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32 Tascano, Patrick "Gunter's Chain" *Surveying and Land Information Systems*, Vol. 51, No. 3, p 158 (September 1991), *Dunn v. Hodges*, 21 me. 76 (1842), *Otis v. Moulton*, 20 Me. 205 (1841), *Machias v. Whitney*, 16 Me. 343 (1839), and *Heaton v. Hodges*, 14 Me. 66 (1836)

33 *Western Mining & Manufacturing Company v. Peytona Cannel Coal Company*, 8 W.Va. 406, 437 (1875)

34 *Day v. Wood Lumber Co.*, 78 W.Va. 19, 22 (1916), *Holston v. Vaughan*, 74 W.Va. 558, 560, 82 S.E. 390 (1914), *Harman v. Alt*, W.Va., 71 S.E. 709 (1911), *Stewart v. Doak Brothers*, 58 W.Va. 172, 175-176 (1905), *Ulman v. Clark*, 100 F. 180, 189 (W.V. 1900), *Gwynn v. Schwartz*, 32 W.Va. 487, 495 (1889), *Ruffner's Heirs v. Hill*, 31 W.Va. 428, 437 (1888), *Western Mining & Manufacturing Company v. Peytona Cannel Coal Company*, 8 W.Va. 406, 418 (1875), *Machias v. Whitney*, 16 Me. 343 (1839), and *Heaton v. Hodges*, 14 Me. 66 (1836)

35 *Winding Gulf Colliery Co. v. Campbell*, 72 W.Va. 449, 467-468 (1913), *Ralston v. Groff*, 55 Pa. 276 (1867), and *Lodge v. Barnett*, 46 Pa. 477 (1864)

36 *MacCorkle v. City of Charleston*, 105 W.Va. 395, 402, 142 S.E. 841 (1928), *State v. Hicks*, 76 W.Va. 508, 510-511 (1915), and *Wing v. Wood*, 13 Me. 111 (1836)

> The descriptions in deeds are usually prepared by surveyors who compose the calls with reference to the lines as they exist on the ground. Surveyors are not informed of or concerned with the fastidious refinement in the use of language favored in some courts." *MacCorkle v. City of Charleston*, 105 W.Va. 395, 402, 142 S.E. 841 (1928)

> Remoteness, land values, habits and education of the people, and other things, did not tend to promote accuracy." *State v. Hicks*, 76 W.Va. 508, 510-511 (1915)

Other errors were a product of the time. Many of today's practitioners will no doubt attest to the fact that the invention of the typewriter was a welcome invention and prevented numerous errors previously caused by interpreting poor handwriting, smudges, and faded ink. The pencil and paper taken for granted by the modern practitioner and used to record information and jog the memory were rare and quite valuable in the past. The ink bottle and quill pen used by the early practitioners was not easily used in the field. The early surveyor was attuned to using knots on a thong, notches on wood, or sticks in a pouch to keep track of measurements. The slide rule and calculator which has eased the burden of tedious calculations and removed the cause of many math errors was beyond comprehension at the time most surveys were performed. All calculations were done long hand.

This article is a brief summary of the many sources of errors in old measurements. A particular locale or name of an early surveyor may offer more particular reasons for differences. The attorney or paralegal, no less than the surveyor, should keep these facts in mind especially when interpreting descriptions where directions are stated to the nearest degree or fraction of a degree and distances to the nearest rod or fraction of a rod.

> In closing this report, it may not be improper to call attention to the fact that the various litigations and disputes about boundaries, which our courts of justice are constantly called upon to decide, are most of them either directly or indirectly the result of the present loose and imperfect method of conducting land surveys. This evil is not, however, it must be acknowledged, confined exclusively to the surveyors. Many of our lawyers, who are entrusted with the drafting of instruments of conveyance, are often deficient in the knowledge requisite to render their descriptions of land correct and to place them beyond the possibility of a misconstruction. *Variations of the Magnetic Needle, Report of the Commissioner on the Variations of the Magnetic Needle*, State of Maine, p. 74, 1866.