Comments on CDR Bauer's *The Sextant Handbook, Adjustment, Repair, Use and History* (Camden, 1986):

Reference works
I used works available to Bauer when he wrote his work:

[1] D.W. Waters, *The Art of Navigation in England in Elizabethan and Early Stuart Times*, (London, 1958)
[2] C.C. Cotter, *A History of the Navigator's Sextant*, (Glasgow, 1983)
[3] W.E. May, *A History of Marine Navigation*, (New York, 1973)
[4] A. Breusing. Die Nautischen Instrumente bis zur Erfindung des Spiegelsextanten (1892)
[5] E.G.R. Taylor, 'The Doctrine Of Nauticall Triangles Compendious, I – Thomas Hariot's Manuscript', In: The Journal Of The Institute Of Navigation , Volume VI (1953). (yep, Hariot is with one 'r').

I use [4] only once as I could not find the information (Levi Ben Gerson's name as first decriber of the cross-staff) in it in other works in my archives prior to Bauer's, so it is only to show that the information was known and available (I could not check it, but it should be available in F. Maddison, *Medieval Scientific Instruments and the Development of Navigational Instruments in the XVth and XVIth century*, (Antiga, 1969), p.47, I took that reference from a more modern standard work: *The Cross-Staff, History and Development of a Navigational Instrument* by W.F.J. Bruyns, (Zutphen, 1994)).

In addition to that the period standard works of William Bourne (A Regiment for the Sea, 1574) and Davis (Seamans Secrets, 1595-1657) could have provided invaluable information (the first was available as transcription by E.G.R. Taylor (1963), the latter as facsimile by the Hackluyt Society (1880) and can nowadays also be found as transcription on the internet:
http://www.mcallen.lib.tx.us/books/seasecr/dseasec0.htm).

Bauers book
Chapter 1 of Bauers book is called 'A Short History' and runs from page 17 to 35. Being a researcher of early navigational instrument (roughly up to 1700) I was especially interested in what Bauer had to say about this period. This post will deal with that period only as I think that others on this list are more capable in judging the development after 1700.

The chapter is presented chronologically:

- Polynesians latitude hook
- Kamal
- A modern latitude hook
- Astrolabe
- Quadrant
- Cross-staff
- Backstaff
- Nocturnal
- Newton's double reflecting instrument
- Hadley's double reflecting instrument
- Godfrey's double reflecting instrument
- Sextant

Before I give my comments on this chapter I want to note that I found two parts that were new to me: the use of a kind of Latitude Hook by Col. Warren Davis (too bad he does not mention the period it was used) and the directions in Bowditch' *American Practical Navigator* to create a makeshift cross-staff. I would be pleased if one of the list members supplied me with a reference to and/or copy from that section.

Summary
In general most sentences by Bauer do contain something of the truth. The problem I have with it is that Bauer did not show any development in these instruments, while all of them have been used at sea for at least a century and a half, developing over time. Instead he shows the situation of most of the instruments as it was when they just arrived (so lets say the first 10-20 years of their use in the field). He does show this development for the sextant by beginning on the first (or rather third, historically seen) reflecting instrument, so we can appreciate the improvements they went through. By not showing the development of the earlier instruments Bauer does not do justice to early instrument makers and their users, instead he tends to show the negative aspects of them and in some cases he does so for the navigational skills of their users.

Let me give a comparison to a subject we are much more familiar with in order to explain what I mean. Suppose I were a car dealer, which sets of slogans would I use to sell a car?:

Set A:

- cars pollute
- cars cause traffic jams
- cars kill people

Set B

- cars are fun
- cars are comfortable
- cars allow you to take your whole family wherever you want

Both sets are completely true, no lie about them at all, but Set B would give me more profit. I could even expand Set A this with historical 'data' like:

- cars did not go faster then 20 kmh
- cars were unreliable
- cars leaked plenty oil
- cars used a whole lot of fuel

Again no lies told, the first Mercedes drove a staggering 18 kmh, old American cars do consume fuel at vast amounts (compared with modern European/Asian ones) and when they get older they do leak plenty oil. Now if the future reader finds himself in an era without cars, he would not understand why people ever wanted to have a car at all, a horse seemed to be a better means of transportation. No pollution, no road kills, speedy, reliable means of transportation and perhaps even no traffic jams (although that might not have been the case).

Bearing this in mind I will now continue with my comments on Chapter 1:

p.18 "At least they [Latitude Hook and Kamal] could be used at sea - an attribute sometimes sadly lacking in a later development - the astrolabe. An elegant instrument, there were some models that looked more like jewelry or artful decorations than practical measuring devices. ...the ocean navigator had to interrupt his voyage, ferry equipment ashore and take sights from there. Many thought that was too much trouble and just pressed on with fingers crossed."

Comment: Two different kinds of astrolabes exist: the astronomical ones and the mariners'. The astronomical ones (made for use on land) consisted of a base, several plates with stereographic projections of the heavens and a rete that showed the stars. These indeed look almost like jewellery especially because of all the star pointers (http://www.astrolabe.ch/img/i_peuerbach_400.jpg) and were of little use at sea due to their solid bodies and lack of inertia. In contrast to the astronomical astrolabe the mariner's astrolabe was a very simple instrument [2:p.47], just as Bauer shows on page 22. They have been used at sea for several centuries and described in period literature up to the start of the 18th century. In Waters [1:p.57] we find the following text on the early use of the instrument:

"The original sea-astrolabe was not very satisfactory instrument. The users found it impossible to take observations within 4-5 degrees 'however little the ship rolls'. But the development of the cast brass model [shown by Bauer on page 22] turned it into a useful instrument. Even so the navigator preferred to go on shore…"

So Waters is telling us a more nuanced story than Bauer. The later brass version became a useful instrument and instead that one <u>had</u> to go on-shore, one <u>preferred</u> to do so, which is quite a difference (and also true for sextant users). At later date the instrument even was recommended by Borough [1:p.157] and by Davis [1:p.202] who in 1657 still found it "… an excellent instrument…" (that is the same Davis who still is famous for his backstaffs). It was used from at least 1481 [1:p.46-n] well into the 17th century [1:p.460-1] (2 survive bearing the year 1648), which is at least 150 years of recorded use.

I have not been able to find reference to Bauers remark "Many thought that was too much trouble and just pressed on with fingers crossed.", instead Cotter [2:p.53] shows us that "… when there is need you must do as well as you may." (quote from Thomas Hariot). Of course they did pressed on when they were unable to observe a star or sun (e.g. in clouded weather), but they did not miss any opportunity to get a latitude (you can check this in period logbooks).

p.18-20 On the quadrant Bauer says that it "could tolerate a small amount of motion" and as with the astrolabe assistance was required. "…it was the most advanced instrument Columbus had aboard his first voyage."
Comment: first of all the chronology goes wrong: the quadrant was in use at least 20 years before the mariner's astrolabe[1:p.46-n][2:chapters 3&4]. Secondly both instruments could be used by a single observer, no assistance is needed when observing the sun, only when observing Polaris. Bauer is implying that it would have worked better than the astrolabe. Cotter opposes this [2:p.36]. John Davis wrote in his Seaman's Secrets that it was "…an excellent Instrument upon the Shore, to perform any Astronomical Observations, but for a Seaman it is to no purpose…". The amount of motion is perhaps even better dealt with on the astrolabe than on the quadrant as the astrolabe has much more mass in the suspended part (thus more inertia). The true advantage of the quadrant are the larger scales on an instrument of the same size [1:p.302]. Bauer lets the reader think that the quadrant was superior to the astrolabe by writing that the quadrant was the most advanced instrument Columbus had aboard. This might be true for that particular event or year, but not in the overall history of both instruments, which is easily understood when you realise that the mariner's astrolabe was only just introduced at sea and still evolving into a better instrument (which took several decades). The astrolabe was that new that Columbus might not even have understood the instrument fully (early quadrants had only ports marked on them, no degrees, but I am not sure which type was used by Columbus). See http://www.millersville.edu/~columbus/data/geo/ODLCASE1.GEO, search for 'astrolabe' and you will find the following (which might have not been available to Bauer, at least not on the internet, which did not exist yet.):

> He tries his hand at
> celestial navigation but fumbles. In his day he did not have
> instruments of precision, and the art of celestial navigation was
> in its infancy. Neither he nor his shipmates knew very much
> about it. His observations of Polaris for latitude were of no
> use to his navigation, because he never knew the proper
> corrections to apply. His "Journal" reveals that he was unable
> to use the astrolabe knowingly in his first voyage, but for
> having an eye for dead-reckoning navigation, Columbus was superb.
> He took his course off his mariner's compass. This instrument
> was the most reliable and most indispensable of his instruments
> aboard.

p. 20 on the cross-staff Bauer wrote that it "was contrived, very likely by a ship's carpenter at the direction of some desperate navigator."
Comment: The cross-staff was first described by Levi Ben Gerson in the 14th century and was used for astronomical observations on land [4:p.74]. In the early 16th century it was adapted for use at sea by the Portuguese [2:p.64]. So the cross-staff was intentionally adapted for the use as a navigational instrument after being used on land for some 200 years, not from despair. Funny thing is though that there is at least one recorded example that a ship's carpenter made one for a desperate navigator, but that was because his ship was blown up after fire hit the gunpowder magazine and the surviving crew ended up in two of the sloops and all the navigational equipment was lost, including his cross-staff. The story is the famous trip of Captain Bontekoe to Batavia in 1619, his popularised logbook has been a best-seller in The Netherlands ever since (http://en.wikipedia.org/wiki/Willem_Ysbrandtsz._Bontekoe).

p. 20 "...the scale on the staff converted inches, which were being measured, to degrees of altitude by trigonometric function"
Comment: What is measured is the angle at the eye between horizon and the celestial object or the sun (which of course is a celestial object as well) by shifting the transom along the staff. Why Bauer uses this rather confusing description I do not know, but it took me several times reading before I fully realised what he meant. Still now I think he should not have written that 'inches … were being measured' as there was no

such scale on the staff (and the reader might get that suggestion). The cross-staff is nothing else than an improved latitude hook or kamal, so why does he come up with that description here?

p. 20 Ocular parallax could cause errors of as much as one and a half degrees.
Comment: In principle this is true, it is even said so in period literature, but it needs some explanation. First of all it entirely depends on the measured angle and the size of the cross-staff and/or vane and whether or not you correct for it. The ocular parallax is caused by the difference between the centre of the eye and the eye-end of the staff, measured in the direction of the staff. The total error in the measured angle depends on the altitude measured and the vane used (the largest vanes found on cross-staffs being 70 centimetres). When measuring low altitudes using a small vane it is impossible to get a degree and a half parallax, as that would be an error of several inches along the staff. The same applies to higher altitudes using the largest vane. At altitudes around 90 degrees with smaller vanes, this could have happened, but one was advised to use the astrolabe for altitudes above 50 degrees as measuring 90 degrees altitude would confront the navigator with a much larger problem: blinking up and down with the eye to get the readings right [2:p.52]. Bourne advised in 1574 to "…pare away a little of the ende of the staffe…" to correct for ocular parallax, but Digges thought this was mal-practise in 1576 [1:p.135,143]. A lot of effort was done to prevent ocular parallax. The best method became available in 1595 and was done by mounting two vanes on the staff each at the same altitude on their corresponding scales and then check what the best position for the staff near the eye was [John Davis *Seamans Secrets* 1595] and this method was from then on described in most period rutters and sea atlases. So, yes Bauer has a point, but so do I when I say a modern sextant can result in errors of several degrees (when badly used and ill maintained/adjusted).

p.20 "Cross-staff sights were only approximations by modern standards"
Comment: Apart from the question whether or not you should compare it to modern standards (I will leave that in the middle), this again depends on the period you are looking at. In the beginning this certainly is true, but in the 17th century the cross-staff improved a lot [2:p.81-83] and became the most reliable instrument. It even resulted in banning the Davis Quadrant from the Dutch VOC vessels by 1731, while the octant was not allowed on board until 1748 (but these last two facts Bauer probably could hardly have known, unless he studied Dutch archives). The improved cross-staffs were well capable of measuring with arc-minute accuracy. Compared to my modern standards as a hydrographic surveyor the sextant is as much as an approximation as the cross-staff was in his days, even worse when relatively compared.

p. 21 "One such practical development was the deliberate introduction of error to eliminate later doubt"
Comment: It is unclear to me what he tries to say here. Was it the shortening of the cross-staff to correct for ocular parallax (he mentions this on p. 20) or was it that in running down the latitude a navigator would choose a deliberate higher or lower latitude (that is what follows in the next paragraph)? If it is the latter (that is my guess), do we speak of an error then, I do not think so. If you rock your sextant to be sure you have the observation done with your instrument vertically, is that 'introducing an error to eliminate later doubt' or is it a procedure to be sure that you get the required result?

p. 21-22 About the invention of the backstaff by John Davis
Comment: It was already known that it was not Davis (we do not know when he invented his instruments, but he described them in 1595, not 1590), but Hariot who described backward observations before Davis did (Hariot described it in 1594 and Davis claims that he designed one of a new and superior pattern to those already known), but even nowadays Hariot is not being named for that, so I will not blame Bauer too much on that [5:p.134-135]. Where it goes wrong is that Bauer continues with describing an instrument Davis did not invent, but only was named after him (but not so before the 1680's) as he made the concept work: the Davis Quadrant. Davis instruments (we are only sure he made two) only had one arc or an arc and a sliding transom, but not two arcs [2: chapter 6]. It is not known who invented the Davis Quadrant (so the instrument with two arcs), but it was first depicted by Waymouth in 1604 [1:p.258-n2].

p.22 "the sum of the readings of the two arcs equalled the altitude of the sun.
Comment: the sum gives the zenith distance of the sun, not the altitude. Figure 6.8 in Cotter's work [2:p.100] shows it as Bauer describes, but so far I have not seen this configuration on surviving Davis Quadrants (and I did see quite a few already). Bauer might have taken this from Cotters book then.

p.22 "a mirror was added, but that came later"
Comment: As far as I know no mirror was ever attached to the Davis Quadrant, but if someone knows of such an addition I would certainly like to hear of it. Additions that were made were the Flamsteed lens (invented by Robert Hooke, I recently found out thanks to Ted Gerrard) and the artificial horizon (invented by John Elton).

p. 24-25 figures 1-7 and 1-8
Comment: both figures show the Davis Quadrant with the horizon vane mounted the wrong way around, which will result in a degree or more parallax, depending on the measured angle. The main beam of the Davis Quadrant has a little hole in it that was used to engrave the concentric circles and the graduations. It therefore is the centre of the instrument and that is where the observation should be done. The horizon vane is flat on one side, stepped on the other and cannot be slid beyond this hole due to the way the main beam is cut (being wider after the hole). If you flip over the horizon vane by 180 degrees the surface of it will be about a quarter of an inch too far to the front of the instrument and therefore not in the centre of the arcs, introducing parallax. In a book that deals with instrument corrections/calibrations this is quite significant (just as the part on ocular parallax on page 20).

p. 25 on the nocturnal Bauer writes: The star clock could be read only to a rough approximation of the time, not good enough for modern navigation.
Comment: He is right, but there was no need to mention this as even if the nocturnal would read down to the second it would be useless as what it measured was local time, not some sort of standard time as GMT or UTC (I do realise that GMT and UTC both came much later, but that is not the point).

p.25-26 on the first double reflecting instrument.
Comment: this is the only comment I would like to make on reflecting instruments, I hope others will contribute on the rest. On page 26 Bauer wrote “He [Dr. Hooke] disputed the originality of Newton’s concept or model or both. We cannot tell which.”. Incorporating Hooke’s 1666 single reflecting instrument would have clarified a lot in this context [2:p.104].