

THE SUNDIAL GOES TO WAR

MALCOLM BARNFIELD

Technological innovations developed during World War II, such as radar, jet engines and electronic aviation navigation, defined the last half of the 20th century and were instrumental in the successful execution of the war. At first glance, it seems unlikely that medieval technology would be useful in 20th-century warfare, but once one realizes that much of the war was waged in areas where more modern technology was either not available or useless, it becomes obvious that the old ways may well be the best ways.

Such an environment was the Sahara Desert where mapping was nonexistent or impractical. Desert navigation has been a problem for travellers, and warriors, since the dawn of time and the methods used by caravans and nomads to find the way are as useful now as they were 2,000 or more years ago.

This article deals mainly with the military use of the solar compass during World War II (1939-1945) and after. Obviously some of the instruments had been developed prior to WWII and used knowledge from pre-WWII: many sun compasses were pressed into service during that conflict and new developments did also appear.

The purpose of any compass, solar or magnetic, is to locate, as accurately as possible, the direction of true north. Once north is found, the current or desired bearing can be determined. Positions are determined with dead reckoning or by reference to a chart or map. Knowledge of the bearing is critical for ocean or desert travellers as it avoids the distinct possibility of going in circles

Most solar compasses are actually an adaptation of the analemmatic sundial which is rather old and came from French mathematician Antoine Parent in 1701.¹ The standard horizontal format sundial is oriented to true north and works by using a calibrated hour curve (part of a conic section) indicating local apparent solar time (LAT) for a given latitude and date. The time is indicated on the plane by using a suitable vertical stylus/gnomon to create a shadow. The Equation of Time adjustments on this dial are incorporated by using a calendar scale along which the sliding stylus can be moved throughout the year. So, when orientated to true north, the current LAT is revealed for that day and in that place.

The solar compass works in the reverse order of this: when LAT, date and latitude are known, and when the dial is set to these parameters, true north is indicated by the compass as the midday position, its dial plate having been calibrated for many latitudes.

Archeological records show that Viking mariners used a form of solar compass in the early 11th century AD and probably before.² The discovery and calculation of conic curves for sundials is attributed to Apollonius of Perga in ancient Greece, as is the naming of the resulting parabola and hyperbola. The theory was further developed by the Persian scholar and poet Omar Khayyám, but he was only born in the mid-11th century AD and no record of Viking/Greek communication exists. A completely plausible explanation of how the Vikings may have achieved their solar compass is given by Folkard & Ward³ and by Cowham⁴ who produced a replica compass to test his theory.

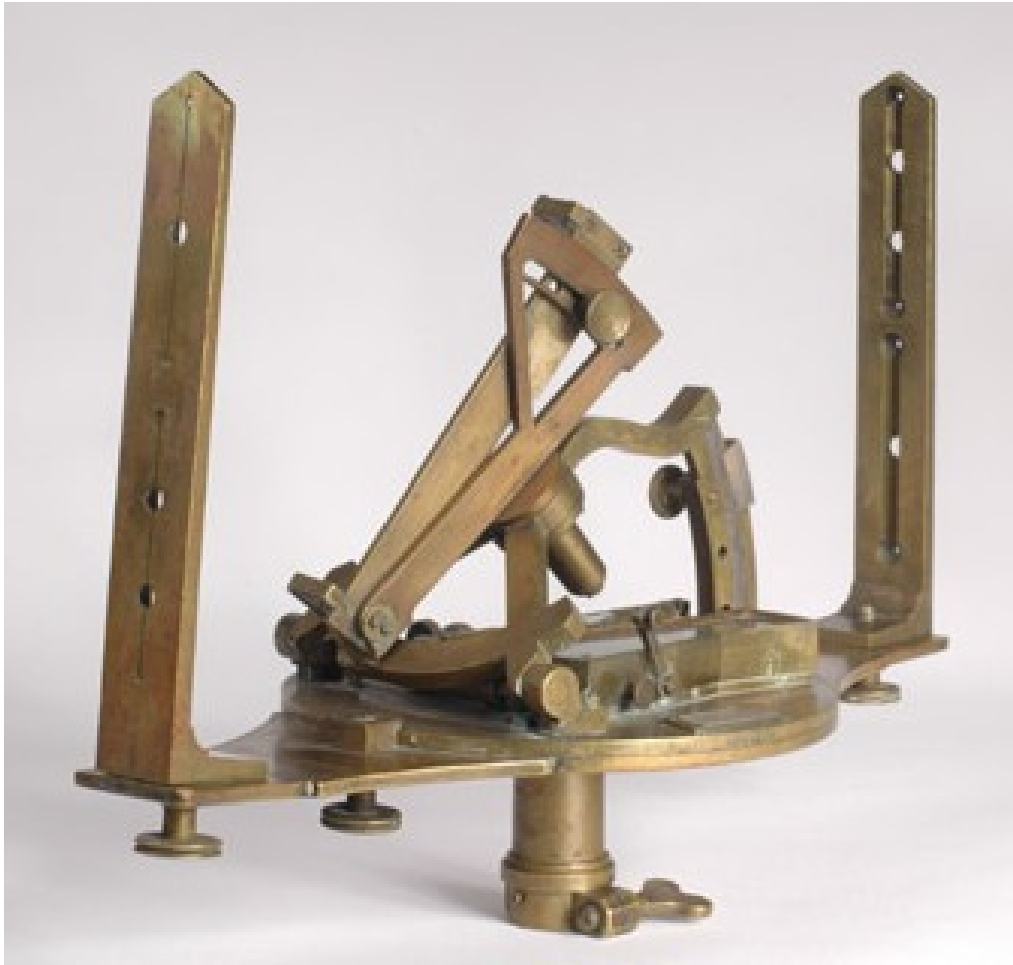
Many fine examples of analemmatic sundials have been made over time and their construction continues as several recent BSS Bulletins show.⁵

Centuries later, when North America began to develop, the solar compass came back into use and William Austin Burt⁶ obtained an American patent⁷ for his solar compass in 1836. The device (Fig. 1) was used to survey and map mining areas where the iron content in the ground precluded the use of the magnetic compass. Burt explains its use in the following way:

To run a north and south line with the solar compass. Set off the declination of the sun on the declination arc. Set off the latitude of the place (which may be determined by this instrument) on the latitude arc. Set the instrument over the station, level, and turn the sights in a north south direction, approximately by the needle.

Turn the solar lens toward the sun, and bring the sun's image between the equatorial lines on the silvered plate. Allowance being made for refraction, the sights will then indicate a true north south line.

Burt's book 'A Key to the Solar Compass & Surveyor's Companion' is still available.



*Fig1. The Burt Solar Compass .
Picture courtesy of the
Wisconsin Historical Society.
Catalogue #1962.60.2,a.*

Later, the Wright brothers flew the first aeroplane and this fascinated a young Talbot 'Ted' Abrams who by 1916 was working for the Curtiss Aeroplane Company, building early aeroplanes. He learned to fly at the Curtiss Aviation School and his Fédération Aéronautique Internationale pilot's licence, number 282, was signed by Orville Wright himself.⁸ Abrams then went into aerial survey photography but found the cameras and compasses then available quite inadequate for accurate mapping. So he founded the Abrams Instrument Company and developed his own instruments. One of those instruments was the Abrams

Solar Compass. It is discussed below.⁹ Unfortunately no picture of the original instrument could be found. The company still exists and now specializes in electronic instrumentation.

Thus, there were commercial sun compasses available before WW II.

After the 'Phony War' phase of World War II in 1939 and the 1940 disastrous British 'victory' at Dunkirk,¹⁰ the real action was about to begin in the North African deserts, first against the Italians and then against the German Afrika Korps led by Field Marshal Erwin Rommel.

The first part of this conflict with 'Wavell's 30,000' against the Italian 150,000 mostly ran along the wooded and hilly coast of Egypt, Libya and Tunisia and resulted in some stunning tactical victories for the British but later, after the Italian defeat, when the Germans joined in, heavy fighting took place up to 950 miles into the Western Desert of Egypt and Libya. These territories were largely unmapped so grid/magnetic compass variation was very difficult to establish. Since the sand dunes were constantly moving with the wind, no fixed point of reference existed, so even if maps had been available they would have been of little use.

The all-steel Abrams Solar Compass (Fig 2) was actually a licensed version of the Kaufman Solar Compass to which American patent 2441636 later applied.¹¹ It was calibrated for both hemispheres and from the Equator to 45° north and south of it, in 3° divisions. Several different length styluses were provided, the tallest of which would have been used within the tropics and the shortest in conjunction with the others for night navigation by orientation to Polaris, the north polar star. The tips of the styluses contained a tiny glass capsule apparently filled with a luminous substance and was presumably used at night but its exact function and method have yet to be discovered. The date plate was calibrated for both northern and southern latitudes. Thus the instrument was

immediately usable in either hemisphere and so was consistently universal within its calibrated latitudes, unlike most others.

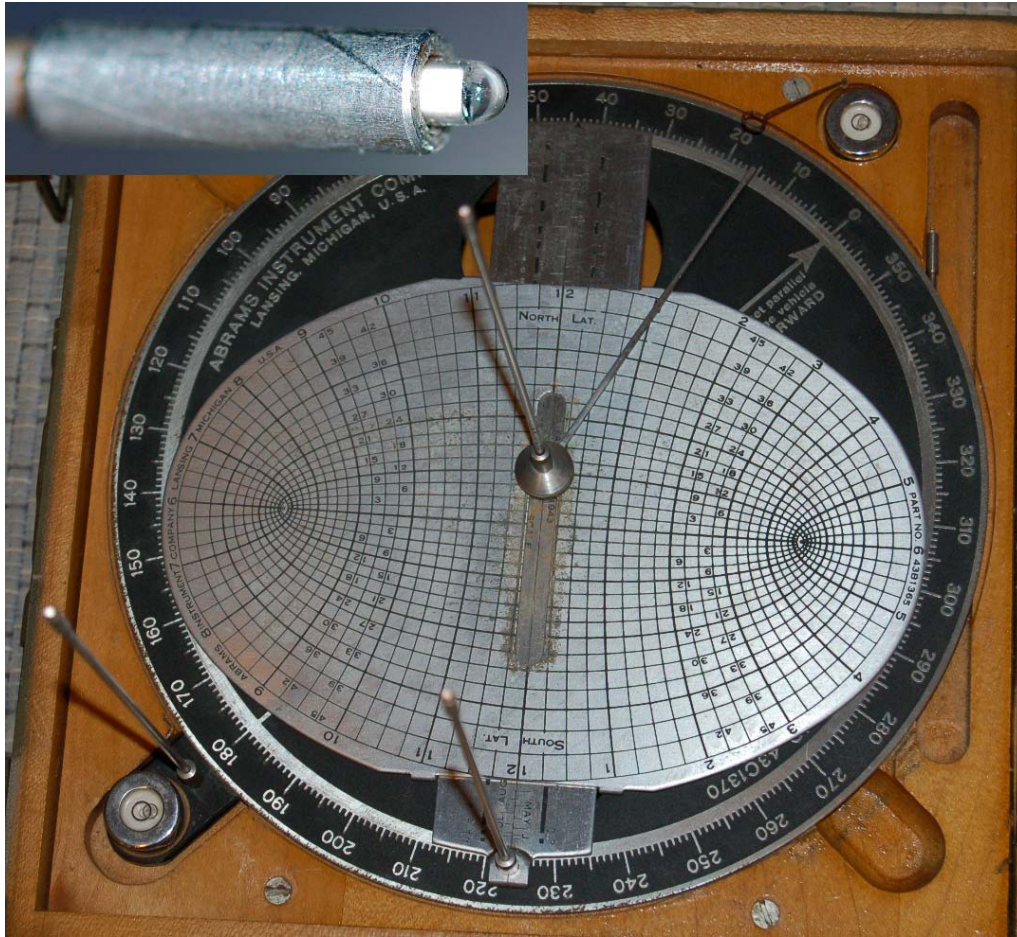


Fig2. The Abrams Sun Compass. Inset: The glass tipped gnomon. Photos by Bill Gottesman

American-made B-24 Liberator bombers, operated by the RAF and U.S. Army Air Corps (later USAAF) in the North African campaign and also the American forces who invaded Morocco and Algeria during Operation Torch late in 1942, were all equipped with the Abrams instrument. It allowed aircrew to find their orientation in the unmapped desert if the plane crashed. Very little of its use or popularity could be learned from research although it was also used by U.S. Forces in the Philippines. Several good examples survive in various museums and private collections and many web articles and pictures exist.

Another sun compass used in the North African desert campaign was the Cole Universal Sun Compass Mk 3, shown in Figs. 3 & 4.^{2,9,12} This instrument was calibrated in 6° divisions from the Equator to 36° N and by a further 3° division to 39° N, so it could hardly be called ‘universal’. Its design and operation were very similar to that of the Abrams Solar Compass but, whereas in the Abrams design the whole dial plate moved up or down the date scale with the stylus fixed in the centre, the Universal Sun Compass had the opposite arrangement.¹² The instrument in Fig. 3 was made by the Philips Orient Company in South Africa. The Philips Company still exists and is known in the UK as a map supplier to schools. It is now in the Octopus Publishing stable and an enquiry there revealed nothing about who Cole was, when the compass was developed, how many instruments were made or why the company left South Africa. However, as Fig. 4 shows, at least 661 instruments were made by 11 January 1940. A web auction site recently had a Cole instrument for sale which was claimed to be “c. 1920”.

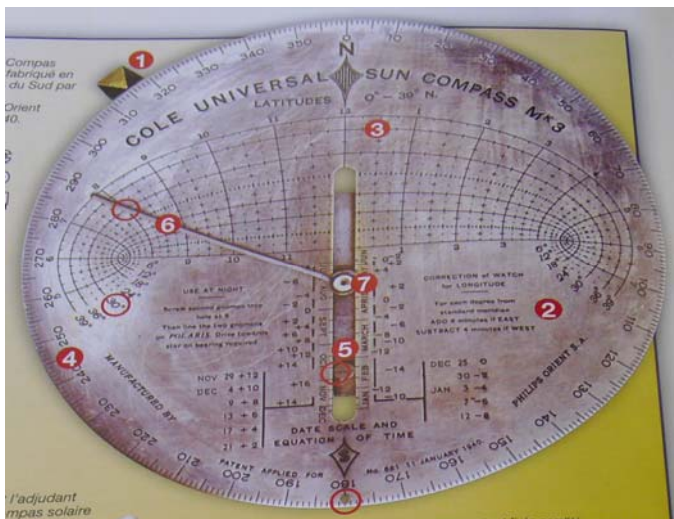


Fig3. The Cole Universal Sun Compass Mk3. After Thierry & Mary Monét.

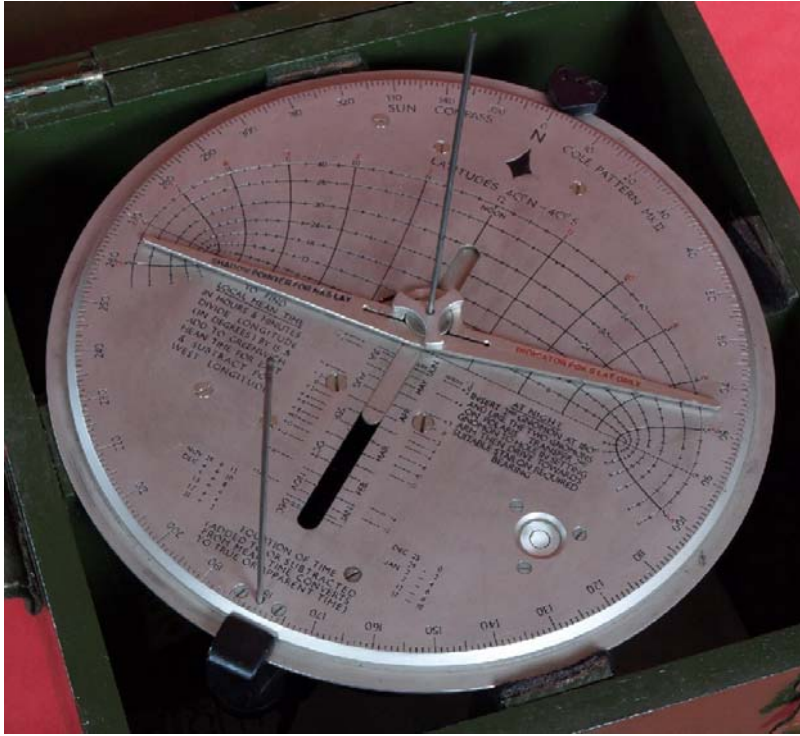
The Cole Sun Compass was particularly popular among the French forces in North Africa.¹² It continued in use until at least 1967. This information is from an old Rhodesian SAS army friend and former Sergeant Major in the French Foreign Legion, who actually used one in 1967. Amusingly, he stated that the “hard bitten Thomases” still slyly checked their results with a magnetic compass, a pointless exercise in unmapped desert conditions. Using a second gnomon also allowed the compass to work by night which close examination of Fig. 3 explains. The South African instrument was definitely made for the North

African conflict only. Proof of this comes from the limited northern latitude calibration (e.g. Benghazi 32° N, Siwah Oasis 29° N), the clockwise hour calibration, and the use of Polaris at night. Polaris is never visible from anywhere inside South Africa. The same applied to the Mk. 2 version.



Fig4. The Cole Mk 3 compass in French Army use on a South African made Marmon Herrington armoured car. North Africa, early 1943. After Thierry & Mary Monet.

Fig. 5 is an English made version of the Cole Solar Compass, the Mk 2, also limited to northern hemisphere use. It is perhaps not as 'soldier proof' as the Philips Orient version but it is equally as effective. It was calibrated to a slightly higher latitude (40° N) than the Philips version as the picture shows. The Mk 4 version of this sun compass was still in British military use in the Iraq 'Desert Storm' conflict of 1991.



*Fig 5. The English made Cole Sun Compass Mk2.
Photo by John Davis.*

The famous British Army's Long Range Desert Group (LRDG) was founded by Major Ralph Bagnold in 1940 mostly, it would seem, by chance.⁶ Bagnold, a veteran of WWI trench warfare and later an old hand in the desert, was on his way to East Africa when the troop ship he was on was accidentally rammed and disabled near Alexandria in 1940. Whilst cooling his heels in Cairo he conceived the idea of the LRDG and approached General Wavell with it. The concept was eagerly approved and a unit of 87 New Zealander officers and men, all volunteers, along with Bagnold and two British officers, was formed.

Navigation was always going to be a problem for this unit and operating far behind enemy lines, up to 950 miles from the coast, was a challenge. Bagnold was a qualified engineer and tackled the problem by using BBC short wave radio broadcasts to obtain GMT and sextants for basic navigation. Initially they used the Cole Solar Compass for following a chosen heading and they even tried the Abrams Solar Compass but both were found to be woefully lacking for delivering the reliable and quick navigation results required. In fairness though, neither was designed for the needs of Bagnold's group.



Fig 6. The Bagnold Sun Compass. Photo courtesy of the Imperial War Museum, London.

In his book 'The Long Range Desert Group 1940-1945', Major General David Lloyd Owen laments this fact and goes on to say:¹⁴

"The compass we used was invented by Bagnold, and the advantage that it gave us over the sun-compasses used by the rest of the Army lay in the fact that it showed the true bearing of the course followed at any moment, whereas the other types only made certain that if the sun's shadow fell on the correct time-graduation the truck was following a set course. This meant that if one had to change course for any reason (and this happened all the time in rough country or sand dunes), the truck had to be halted and the compass set again. This was all very time consuming, and I have never understood why the Army did not adopt the Bagnold sun-compass, which was far simpler to operate, absolutely "soldier-proof" and, I would have thought, cheaper to produce."

The Bagnold compass is shown in Figs. 6 & 7. Later, Owen describes using the compass:¹⁴

“The principle can be briefly described as keeping the shadow from the sun of a vertical needle (which projected from the centre of a small table graduated into 360 degrees) on to the appropriate reading needle in order to maintain the direction required. If one was forced off this bearing it was still possible to read the direction in which the truck was then traveling. There were problems connected with the sun’s azimuth at various times of day and seasons of the year, but those too were overcome by the inventive genius of Bagnold.”

Navigation by the LRDG was precise as is shown by their extraction of the men from the very first of then Lt. David Sterling’s SAS raids in the desert during 1941. Their accurate traverse of the ‘sea of sand’ (dubbed ‘on the blue’ by British soldiers) was easily comparable to that of any Navy Captain’s efforts on the oceans. They also travelled using the moon for direction but whether this was by using the sundial with a moon correction chart or a sextant is not made clear in the literature I have seen. The Bagnold instrument had a set of removable card azimuth plates for different dates and latitudes, calibrated in 3° divisions from 0° to 46° N. Presumably the 46° card only showed 1° of latitude. These were mounted below the compass on the dashboard and were used to set up the instrument. For southern latitudes another set of cards would have been needed but the LRDG never operated south of the equator. However, they certainly found themselves well south of the Tropic of Cancer at times. Waterproofing of the cards was unnecessary – it does not rain in the desert.



Fig 7. The Bagnold Sun Compass on a Canadian made ‘Chevy’ truck. Note adjusting wheel. Courtesy of the LRDG web site.

Using the Bagnold compass was relatively easy, mostly for the driver. Global position and LAT were established by the navigator, around midday, using the sextant, theodolite and GMT radio signals. Armed with this knowledge the driver set the Bagnold compass to the given parameters and established true north. The compass was mounted in the centre of the dashboard usually to the right of the driver since these were often North American-made lefthand-drive vehicles. The orientation came from a central line from front to back of the truck, the lubber line, north to the front. He then rotated the bearing ring of the compass to alignment with the lubber line of the vehicle and onto required bearing and then drove along with the shadow from the stylus on that bearing. If a deviation for a large obstacle was required the driver made the adjustment to the bearing ring with the adjusting wheel, one full turn of the wheel equating to

exactly 2° of bearing alteration. When the obstacle had been passed the driver/navigator simply reset the bearing ring to the original course and continued on his way without stopping the patrol convoy. Even if he did not adjust the bearing, the original bearing could easily be re-established after bypassing a small obstacle by simply bringing the shadow from the stylus back onto the original bearing. When travelling in a southerly direction the back-bearing (bearing -180°) would have been used. Adjusting the bearing to the ever-changing solar azimuth was also performed using the adjusting wheel at regular intervals.

Bagnold ended WWII as a brigadier and with an OBE, fitting recognition to a great mind and a great man, a soldier’s man who ensured his men were well equipped and well looked after thus ensuring willing and effective service to the greater cause. In my opinion Bagnold should be ‘right up there’ with Brahe, Kepler, Hartman, Oughtred and other luminaries of my sundial passion.

Britain’s allies included many Commonwealth countries, most of which had troops particularly suited to the local conditions. One requirement led to the hasty formation of the South African Armoured Car Regiment (SAACR). A tool which this regiment lacked was a reliable navigational capacity in uncharted territory.

In 1940 the Union Observatory (Union of South Africa) at Observatory, Johannesburg, was directed by Prof. W H van den Bos and he was ably assisted by W S Finsen (MSc, later DSc and observatory director). Finsen relates in

Fig 9. Extract from Finsen's journal. Courtesy of the SANWM.

The instrument worked on different principles to the compasses described above. It had a sliding lens that moved along a date scale which allowed the focused beam of sunlight to be projected onto a frosted cellulose target screen that swivelled to the hour calibration after being adjusted to the latitude. Thus it did not employ a gnomon since it worked on solar altitude and not solar azimuth. This compass had several advantages over other designs. It was not necessary to know LAT or longitude to set it. Also, adjusting it to another bearing whilst on the move was possible. It was equally as easy to reset to the original bearing after a deviation for obstacles on the route, like a sand dune or ravine, also whilst on the move. Lastly it was 'soldier proof' and compact being constructed sturdily from solid brass and its moving parts were all closely engineered to prevent the ingestion of sand and dust. Like its 'cousin' the astrocompass, it was usable in both hemispheres without any hardware reversal. Its latitude calibration markings, also like the astrocompass, were filled white and red for the northern and southern hemispheres respectively and were marked from the equator to 60° N and S. However, because it worked on solar altitude, it became increasingly useless above latitudes of 60° because solar altitude at the high latitudes is steadily more constant throughout any sunlit day as the pole is approached.

A then 'Top Secret' but now derestricted letter to the War Office in London in 1940 is on file and offers the instrument to the British. Their response is not recorded but since only 128 of the instruments were made, it was definitely not accepted. Price is nowhere mentioned. Every squadron of the SAACR was equipped with one though. The instruction booklet that accompanies the compass¹⁶ explains three methods for setting-up, one for use within the tropics, another for use outside them and the third a combination of both. The SAACR only ever operated north of the tropic of Cancer during WWII but the instructions are valid for use in South Africa, parts of which are within the tropic of Capricorn. Strangely, the instruction booklet also gives every trigonometric formula used in the design, hardly appropriate for a combat soldier's use.

The SAACR used the Observatory compass to great effect and had a proud record in the desert campaign. Towards the end of the African phase of WWII, the fighting was confined to the narrow coastal plain of Tunisia and its adjacent highlands. Here the solar compass had very little use because the coastline was easily visible and good survey maps existed so the trusty prismatic compass (Fig. 10) was employed instead. After the surrender of African Axis forces in May 1943 the SAACR was sent home and demobilized. A few months later the regiment was resurrected as the South African Tank Regiment and equipped with modern tanks complete with their Observatory Universal Sun Compasses. The unit was eventually deployed around the Mediterranean, Middle East and North Africa. Italy was well mapped so the solar compass found no place there.

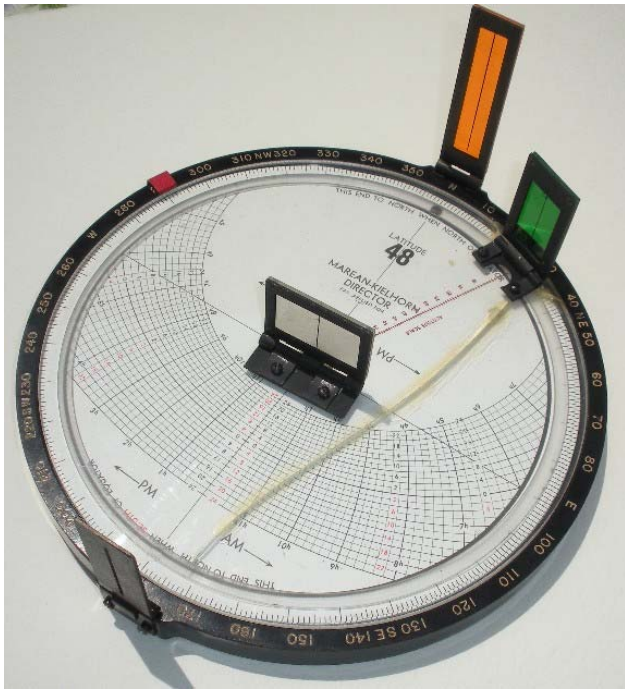


Fig 10. WW II prismatic marching compass issued to BSAP Sgt. Grover in 1939.

A further instrument was developed during this period, the Armstead Sun Compass. Sadly no pictures of the two prototype versions made of this instrument can be found. The compass came from the British Indian Army's need for a solar compass to be used in desert warfare. This compass has been described in the *Bulletin* previously,^{17,18} and Michael Lee has made a fine and accurate instrument¹⁷ based on Armstead's original design. Judging from Armstead's logic and mathematics alone, he must have been a huge asset to his military logistical office. However, as an ex-military man, my opinion of the instrument is that that whilst it demonstrated Armstead's complete understanding of gnomonics, trigonometry and solar geometry and was a very clever concept, it contained too many flimsy parts and screws that would vibrate lose and be lost so it could never have been 'soldier proof'. It was also complex to use, set up and

understand and could not be used on the move, so was never destined for production and use in a mechanised and mobile theatre of war. The basic principles of the Observatory Compass and the Armstead Compass are the same and it is amazing how great minds came up with the same navigation solution simultaneously, albeit continents apart and without joint knowledge of each other's work.

So, was the end in Africa the end for the solar compass? Emphatically, No!



The United States Navy operating in the Pacific Ocean and other areas, against the Japanese and Germans, used the Marean-Kielhorn Director¹⁹ (Fig. 11), their lifeboats being equipped with them. The instrument is based on the Sapha universal astrolabe and is a horizontal stereographic projection for a given latitude, there being a set of plastic cards for many latitudes supplied in the instrument's Bakelite case. In operation, the instrument worked very much like a sextant. It was suspended vertically and an altitude measurement of the sun or a star was taken through the sights. The sights had various filters to allow observation of the sun directly. Unlike the sextant the image obtained was not lowered to the horizon, instead the instrument was then laid flat and the relevant information extracted. Results depended largely on the skill and training of the operator and LAT, true north, sun's declination and right ascension, sun's maximum altitude, time of sunrise and sunset and so on could all be found. The U.S. Merchant Marine used this lifesaving device well into the 1970s. The Marean-Kielhorn Director has been shown recently in the NASS Compendium.²⁰

*Fig 11. The Marean Kielhorn Director.
Photo by Ed Popko.*

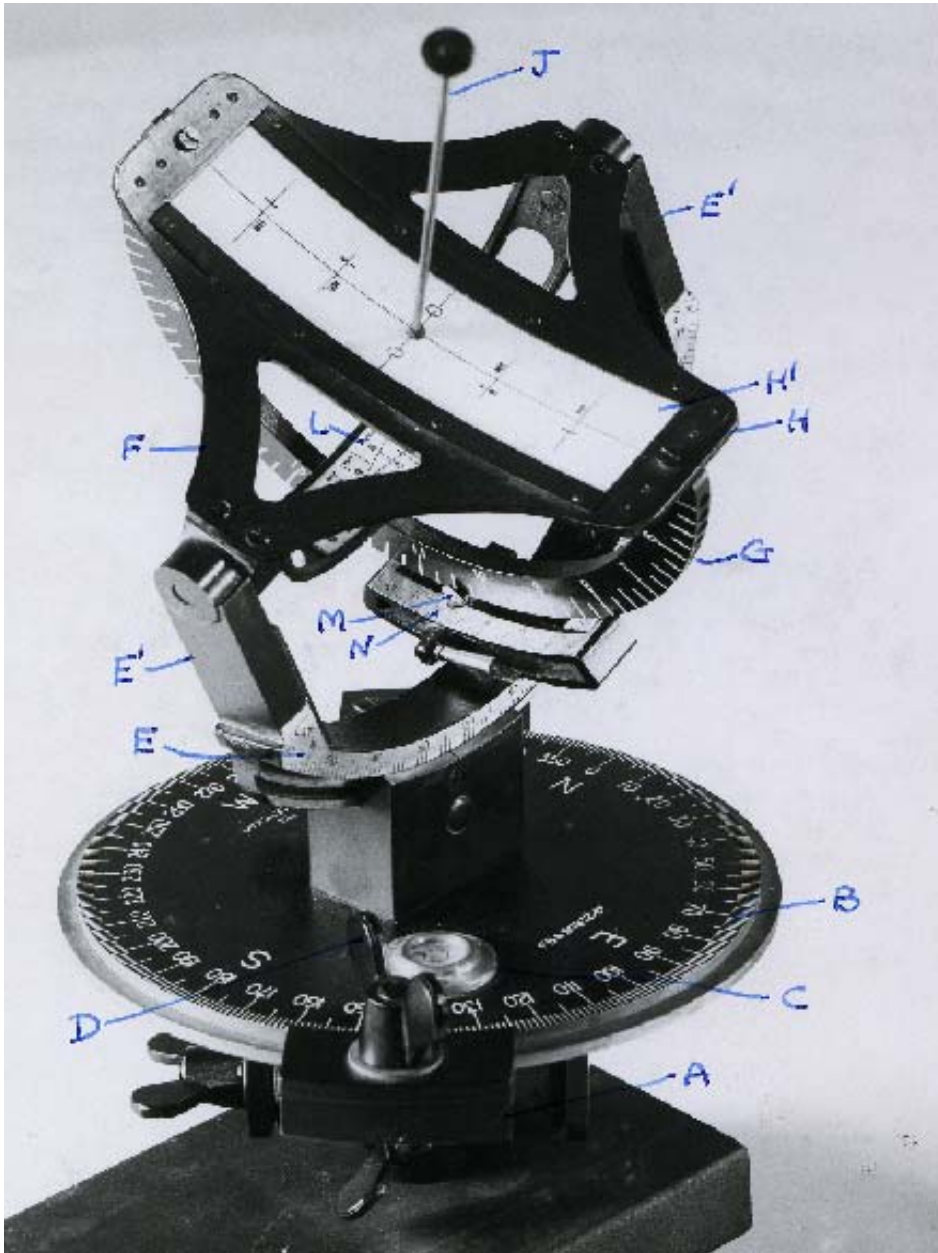


Yet another instrument is the hand-held Howard Solar Compass^{2,9} as used by British Forces until at least 1991 (Fig. 12). I have read a brief on-line article² about the Howard Compass, the instrument being stamped '91' which is presumably the date. Not much more could be discovered about it except that it had been in use by British forces well before WWII. It also used two styluses similar to the Cole Mk 2 & 3 and Bagnold compasses for night-time navigation by the stars.

Fig 12. The hand held Howard Sun Compass. Note the handle. Photo by John Davis.

Two other solar compasses are mentioned by BSS Chairman, Christopher Daniel, in his 'Clocks Magazine' articles.^{21,22} These are the Evans-Lombe and Richards Sun Compasses. The Evans-Lombe Sun Compass was a rather flimsy device consisting of two printed plastic cards which rotated concentrically around each other. A set of 13 cards for different latitudes and dates was provided. It was used by the British Army. However, it seems that

by 1940 it had been superseded by the metal Cole pattern sun compass. Nothing further could be learned of the Richards Sun Compass except that it was presented at the Royal Geographical Society in 1941. The Richards instrument would seem to have been a completely independent development since he appeared to have been unaware of similar instruments already in use. So, perhaps it was only a discussion design. No surviving example could be found.



Even after extensive enquiries with the successors to the Admiralty Compass Observatory the Micklethwait instrument Hickman mentions was not located⁵. The instrument was complex to understand, use and set up but was equally usable in both hemispheres. Fig 13. Latitude, longitude and LAT all had to be known to use it and it was definitely not 'soldier proof'. In the only paper on it that I found²³ Micklethwait himself seems more concerned with BST, GMT and LAT than with direction even though he states that the base of the compass is that of a standard Cole Sun Compass. From this it is easy to see why the instrument never gained vogue and soon slid into obscurity. It was made by the English company Francis Barker & Son Ltd. in 1932.

Fig 13

*The Micklethwait Sun Compass
Courtesy of the Tank Museum,
Bovington, Dorset, England.*

Navigation using compressed gnomonic projection maps and radio signaling to two fixed base stations at known locations and which possessed direction-finding antennae had been available before the 1920s but this method was unsuitable for the desert war.²³ Portable radio technology then was unreliable and of limited range at best, plus, with the ever-changing fortunes of war and locations in that battlefield, this meant that the possible availability of fixed base station signals within the range of radios were always changing. Security was another concern. The constant broadcasting from a 'callsign', looking for a confirmed global position, could easily have compromised the sender's position. It was not only the Allies who had 'ears'. Thus this method of navigation was never used by Allied forces in the North African WW II desert campaign.

A German version of the solar compass is the device made by "C. Plath of Hamburg" and shown in Fig. 14. This was used by Rommel's Afrika Korps in the Western Desert campaign from beginning to end. The instrument had its roots in polar exploration and had a clockwork-driven 24-hour clock. The clock's movement was the 8-day Junghans cal J30D or E model. Otherwise it was a standard sun compass of the type with an adjustable bearing table that lay in the horizontal plane. The clock was set to LAT and true north was established along the vehicles lubber line using the calculation of 4 minutes of time per degree of hour angle change or 15° per hour. Thus it

could also be used at night since grid/magnetic variation could be established. The instrument was also used to calibrate the magnetic and gyrocompasses of planes during ground service periods. At high rates of acceleration and during violent turning both the magnetic and gyrocompass become unstable so the use of the sun compass allowed accurate recalibration to both instruments. Fig 15 shows it in use on a Heinkel 111 bomber plane²⁴. Later it was used to service the compasses of the Messerschmitt Me 262 aeroplane, the first operational twin jet fighter of WWII.



Fig 14. The C Plath of Hamburg Sun Compass.
Note sights.
Photo by Konrad Knirim



Fig15. The Plath Sun Compass in use calibrating compasses in a German Heinkel 111 bomber plane. North Africa, 1940's. After Konrad Knirim.

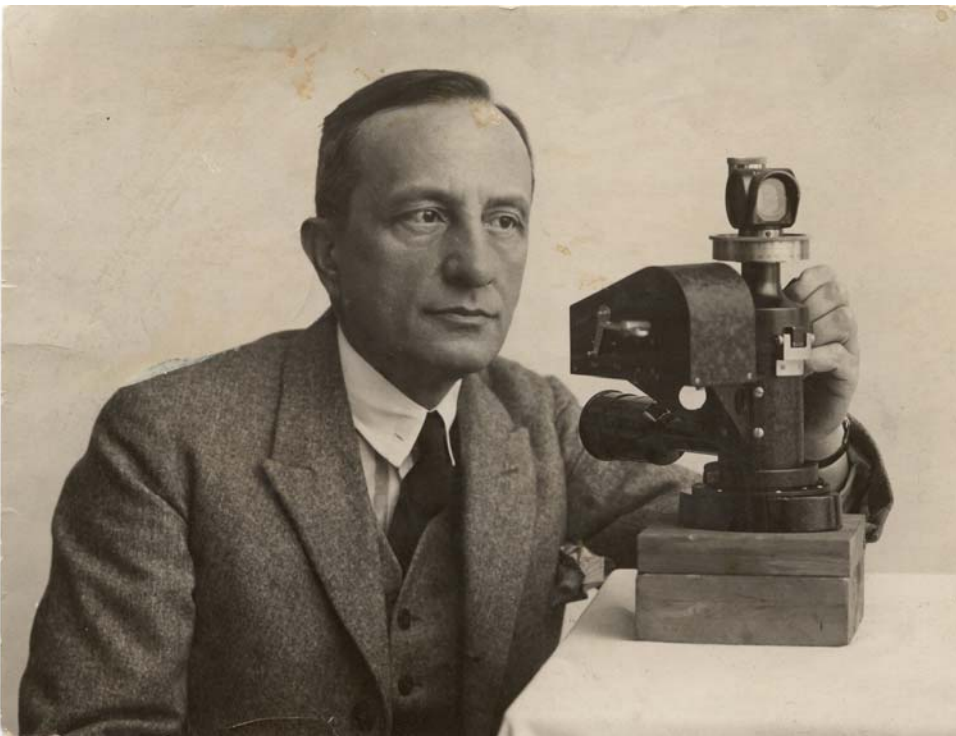


*Fig 16. The Bumstead Sun Compass.
Note sights.*

*Photo courtesy of the Smithsonian
Institute.*

The original instrument of this type was developed by Albert Bumstead in the early 1920s. He was then Chief Cartographer at the National Geographic Society in the USA. It was designed specifically for use by Lt. Commander (later Admiral) Byrd for his attempt to be the first man to fly across the North Pole. It was made by the Pioneer Instrument Company of New York, U.S.A., whilst the development and prototype came out of Bumstead's home workshop. Using the Bumstead compass,

Byrd achieved his goal on May 9, 1926. See Fig 16. This came at about the same time as the parallel and similar development of the Bumstead-type compass from the German company C.P. Goerz of Berlin. Again, great minds came up with the same solution at the same time. The Goerz Company were later part of the Zeiss Ikon A-G optical conglomerate and had a branch in the USA. Surprisingly, their Austrian branch in Vienna supplied the RAF with gun sights even after the German 'Anschluss' (joining in English) occupation of Austria in 1938,²⁵ more than 700 of the RAF's Hurricane fighter planes being equipped with them. The Goerz sun compass was made for Roald Amundsen's simultaneous dirigible attempt at Byrd's goal. Amundsen is better known for beating Capt. R.F. Scott to the South Pole in December 1911. Whether either of them used any solar compass during those expeditions is not known. Scott is known to have used the sextant and a theodolite and Amundsen the sextant.



*Fig 17. Capt. J.M. Boykow and his
Georz Sun Compass. Photo from the
private collection of Oliver Trulei*

The Goerz sun compass was the brainchild of Capt. J.M. Boykow (Fig. 17), a member of the Goerz technical design team.²⁶ For a constant course and thorough a periscope, it projected a reflected image of the sun onto a frosted glass screen with a target line. LAT being known and using the 4 minutes per degree calculation, true north was then established and the 24-hour clockwork mechanism started. That drove the sun's image across the screen from east to west at a constant speed equal to 15° of arc per hour. Adjustments for the ever-changing solar altitude were

possible but unnecessary near the poles since solar altitude is virtually constant at such places. The chosen

heading was then selected from a 360° calibrated and adjustable ring and followed. The pilot had only to keep the mean sun on the target line to maintain the required heading, adjusting his bearing as often as possible to minimize the slightly zigzag path that all navigation by sun compass can deliver. A deviation from that heading was just as easily accomplished as was returning to the original bearing simply by following the chosen bearing and keeping the sun's image focused on the screen's target line.

Byrd went on to be the first to fly across the South Pole in 1929, again using the Bumstead compass. He navigated the flight himself and would have had to contend with some unique polar navigational problems. For instance, you can only face north from the South Pole or south from the North Pole. There is no longitude at those places; the measurement is always zero because all meridian lines converge on one spot. Solar altitude is constant throughout all sunlit times and the maximum solar altitude at the relevant summer solstice is only 23.44° above the horizon and the sun is only visible above the horizon for 6 months of the year. Thus, whilst solar azimuth is constantly changing no indication of local solar noon can be obtained from observation instruments like the sextant, theodolite or astrolabe and till this day all Antarctic base stations use GMT as their time zone, there being no point in using any other. The brilliance of Bumstead in employing the 24-hour clock in his instrument overcame these problems so direction on a chosen bearing could be maintained. In peacetime and post-WWII, polar exploration resumed and once again various formats of the solar compass were pressed into service, the magnetic compass being of little use at such latitudes.

German troops in North Africa were issued with a cardboard cutout horizontal sundial that was calibrated for the various latitudes in which they operated. Fig. 18 is the dial for the latitude of 31° north.²⁷ Most wristwatches then were not waterproofed and so the fine dust of the desert sands literally brought them to a grinding halt. The

sundial remedied the problem to some extent since accuracy was only claimed to within 15 minutes.

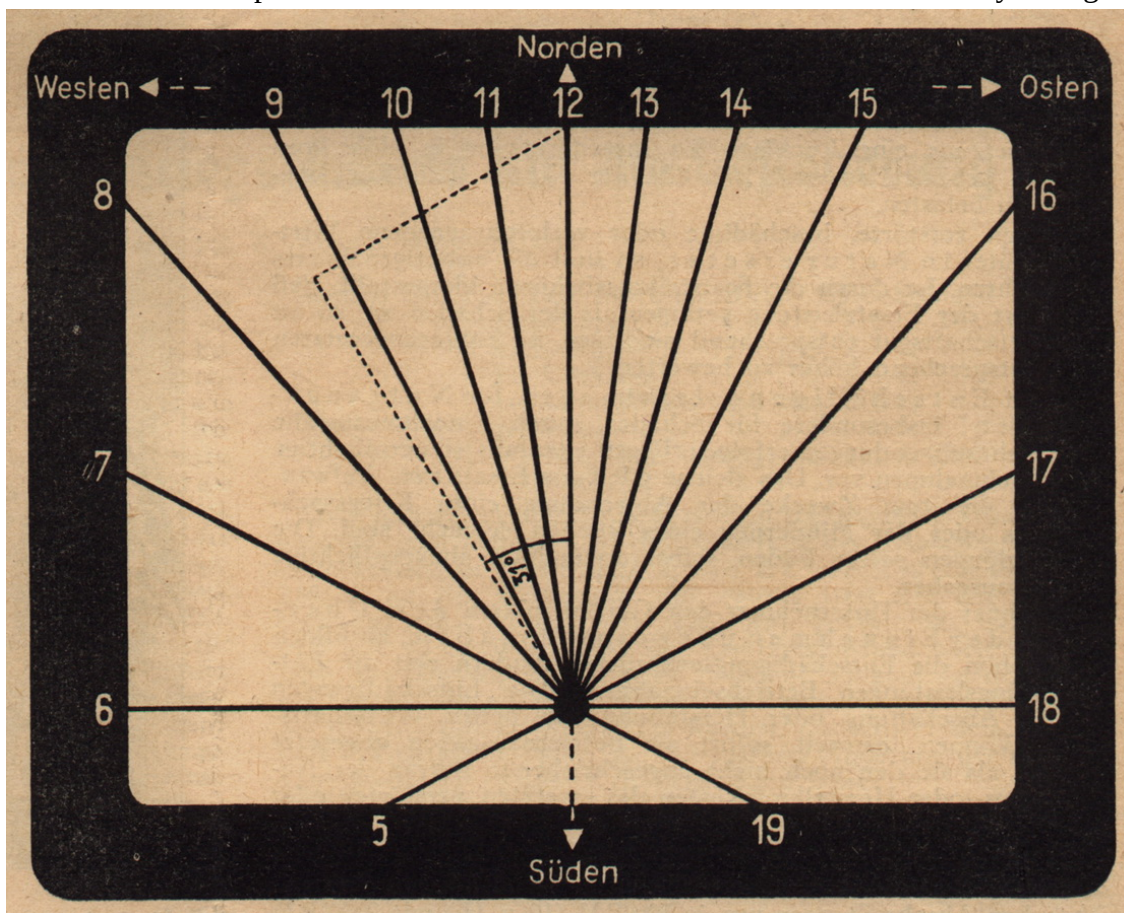


Fig. 18. Cardboard cut out horizontal sundial issued to German troops in North Africa during WW II. After Konrad Knirim.

The astrocompass (Fig. 19)^{9,28} had been in British military use for many years before the war and by early 1940 RAF heavy bombers were equipped with British, American and Canadian versions of them. All seem to have come from a single

British design by P.F. Everitt and all were called Mk II. The basic design came from his earlier Mk IX sextant and initial production was by Henry Hughes & Son of England. There were many other makers: Horstmann in the UK; W.W. Boes Co. and Sperti, Inc. in the USA; and Dep & Co. in Canada. Later versions incorporated features from captured German instruments. This instrument is related to the solar altitude compass in many ways, delivering LAT, Local Sidereal Time at night, latitude, longitude, right ascensions and declinations of both sun and stars, true north and so on, in both hemispheres. It made extensive use of astronomical almanac tables to obtain the required direction after observation of the sun or a star through its sights. It had a weakness when using solar observation near the equator. Here, at certain times of day and year, solar azimuth is virtually impossible to measure since the sun is very high in the sky from early in the day until late afternoon. However it was generally

employed in the higher latitudes with plane ferry flights to England from the U.S.A. and in Europe, China and Japan plus the surrounding islands. Lloyd Owen¹⁴ mentions the same problem with the Bagnold compass. This latitude anomaly was the exact opposite of its Observatory Solar Compass 'cousin'. One huge advantage it held over the humble azimuth solar compass was that it could be used at night, far more accurately than by using Polaris, which is over 2° off true north anyway. Its use in the bombers, where there was a dedicated navigator, obviated the need for the Bumstead/Plath type compass and the single seater fighter planes that escorted the Allied bombers used the direction gyro and magnetic compass. The German Luftwaffe used a bubble octant in the bombers and the gyrocompass with the magnetic compass in the fighters.²⁹ After WW II it continued in use in the early trans Atlantic flights made by U.S.A. based commercial airlines and with many air forces, worldwide.



Fig 19. The Astro Compass Mk II. Photo from NASS Compendium. Sept 2003.

Except in the cases of the Bumstead/Plath type compasses it may be thought that every instrument mentioned above had a fatal flaw: the visibility of the sun or a known star. This was not a problem in the desert but even on the most clouded days at higher latitudes there is always a break in the cloud at some time, however momentary, and a skilled flying navigator could identify a star quickly using his star finder³⁰ and tables of right ascension and declination or get a brief visual sighting directly on the sun. Fixed and known ground features were also used for orientation by both the ground navigator and flier, dead reckoning too, so he always knew his approximate position and heading and thus was able to pre-emptorily know what he should see when a cloud break appeared. It was his job to bring the ship, plane or battle group onto the target and then the final assault was visual anyway.

A seemingly glaring point missing from all the literature about solar compasses is that if true north had been established with the solar compass then the grid to magnetic variation at that place could easily have been established too, and so

navigation by magnetic compass became possible. Many factors militated against this in the desert war. The steel bodies of the vehicles and its magneto or generator could well have caused magnetic compass inaccuracies as could ground minerals; the vehicles had no reliable odometer for distance measurement and there were no maps to work from anyway. There were no known fixed points to work with and, sending out a lone vehicle on a given

bearing and then taking another bearing on the forward vehicle from the command vehicle at the point of origin left that forward vehicle and crew vulnerable to ground ambush and air attack and, most importantly, even a small error in compass reading at the outset would soon translate into a huge inaccuracy after a 100 mile drive. Plus, all of this was very time consuming. The problems went on and on so the method, whilst known, was seldom used and was not the first choice of the LRDG and most others.

No evidence of WW II Japanese or Russian military use of the solar compass could be found. This is surprising, especially in the case of Russia. Their army operated at very high latitudes against the Finns and magnetic compasses would have been unreliable there.³¹ The Italian Army's Auto-Saharan Company, a unit similar to the LRDG, had been operational deep in the Libyan Desert for many years before and during WW II but how they navigated remains unknown. It is known that they had their own spotter planes so perhaps the navigational information came from the air wing. The Italian military made unsuccessful attempts to adapt the Kaufman Solar Compass¹¹ for desert use during 1942.³² The failure of the project would appear to have been because the war theatre rapidly overtook the latitudes for which their version was designed, being 28° to 36° north. How they got the Kaufman design remains a mystery since the design was already being used by the Abrams company for the U.S. military and the U.S.A. and Italy were at war from December 11th, 1941. In any event, other partners in the Axis and Allied alliances had the solar compass technology had it been called for.

A final reference to the sundial at war again comes from Finsen's journal.¹⁵ Here he mentions the Observatory Sun Compass for use in artillery barrage gun laying. Whilst the method was investigated at the time, it seems unlikely that it was ever used in combat since as he says, the war ended.

Now, in the age of GPS, radar, laser and AWACS, the solar compass would seem to have run its course and become redundant but somehow I doubt that. Illustrating this is the fact that after WWII and when military surplus stores began operating, the astrocompass was snapped up by amateur stargazers, its capabilities making their learning of the night skies easy. The army prismatic marching compass became a favourite of campers and hikers. The Evans-Lombe compass was used for teaching purposes in the Boy Scout movement well into the 1970s plus collectors and museums began assembling their treasures. Interest from sundiallists continued and historians joined the quest as many published articles show. Today these instruments regularly appear for sale on and are prized items on auction web sites like eBay. The company of C Plath, now part of the Sperry Marine Northrop Grumman Group in the U.S.A., still make a Pelorus, a basic sighted inshore navigation instrument used to maintain course on a chosen heading. The instrument easily and quickly converts to a sun compass with the installation of the central and vertical stylus provided. In addition, several clever adaptations of the sun compass principles given above are commercially available for the gardener, photographer, pilot, house buyer, tree surgeon, greenhouseman and hiker. Other sun compasses appear on the folding bezels of wristwatches and on Swiss army knives plus even cell phones. Thus the solar compass lives on and long may it continue so.

Apologies are given to every soldier for the phrase 'soldier proof' but as an ex-soldier I know how it goes in idle moments and battle has scant regard for equipment.

ACKNOWLEDGEMENTS

I sincerely thank all of those below whose keen, willing and expert input made this article possible. The list reads like a United Nations register and clearly illustrates the co-operative nature of diallists, scientists and historians worldwide.

Richard Hendrie, curator, South African National Military History Museum (South Africa); Prof. Tony Voorvelt, Univ of the Witwatersrand (South Africa); François Blateyron, diallist (France); Denis Savoie, diallist (France); Dave Curry, military historian (Australia); Malcolm Kriel military historian (South Africa); Dr. Ed Popko, solar instrument collector (USA); James E. Morrison, author of 'The Astrolabe' (USA); John Davis, BSS editor (England); Mike Cowham, diallist (England); Bill Gottesman, diallist (USA); Martin Garnett historian, Imperial War Museum (England); Klaus Eichholz, diallist (Germany); Walter Hofmann, diallist (Austria); Alaksandr Boldyrev, diallist (Russia); Fred Sawyer, diallist (USA); Michael Maltin, diallist (England); Oliver Trulei, historian (Austria); Johan Wikander, diallist (Norway); Konrad Knirim, military historian (Germany); Giovanni Bellina, diallist (Sicily).

REFERENCES & NOTES

1. F.W. Sawyer: 'From Universal Analemmatic to Sun Compass', *NASS Compendium*, 10(3), 18-19. (September 2003) This paper gives an excellent history to the development of the sun compass.

2. www.cadrans-solaires.pages-orange.fr/navigation/navig-uk.htm gives a good overview of the compasses mentioned.
3. M. Folkard & J. Ward: 'The Sun Compass based on an artifact found at Uuartoq Fjord, S.W. Greenland', *BSS Bull.* 98.1 (February 1998). With an introduction by Margaret Stanier.
4. M. Cowham: 'The Viking Sun Compass', *SIS Bull.*, 101, 39-43 (June 2009).
5. M. Hickman: 'Sun Compasses', *BSS Bull.*, 94.1 (Feb 1994). A detailed description of the Howard and other sun compass usage. This article is a 'must' for every student of the topic.
6. www.en.wikipedia.org/wiki/Solar_compass
7. U.S.A patent No. 9428X dated 25 Feb 1836.
8. Abrams Planetarium www.pa.msu.edu/abrams/
9. http://www.zetatalk6.com/docs/Navigation/Maps/Field_Navigation_2004.pdf A very good explanation of usage of the sun compasses mentioned is given at this site.
10. B. Liddell Hart (Ed.): *History of the Second World War*. London, Phoebus (1966).
11. www.freepatentsonline.com/2441636.pdf
12. T & M Monét: *Le Bournos Bleus Sur Les Chemins Du Devoir. Le Spahis Du 1 ER Marocains De 1939a\1947*. Private publication, France (2007).
13. R.J. Vinck: 'The Universal Sun Compass & the Complex Variable', *NASS Compendium*, 10(2), 25-28 (June 2003).
14. D.L. Owen: *The Long Range Desert Group. 1940-1945. Providence Their Guide*. Pen & Sword, London (2000).
15. South African National Military History Museum archives.
16. www.samilitaryhistory.org/vol024mn/html gives more detail on the Observatory Sun Compass.
17. Norman Darwood: A Moondial. *BSS Bull.*, 18.1 (June 1992).
18. M. Lee: A Moondial for the Northern Hemisphere. *BSS Bull.*, 20.1 (Dec 2009).
19. U.S.A. patent No. 2,440,827 (20 Aug 1945). www.freepatentsonline.com/2440827.pdf
20. Sasch Stephens. Marean-Kielhorn Director. *NASS Compendium* 17 (1) 36 (March 2010)
21. C. Daniel: *Clocks Magazine*, (May 2000).
22. C. Daniel: *Clocks Magazine*, (May 2004).
23. F.W. Sawyer: 'Compressed Gnomonic Sundials', *NASS Compendium*, 12(1), 1-8 (March 2005).
24. Konrad Knirim. *Militärühren*. ISBN 3-89355-232-4. Pomp, 2002. pp. 398. Photo of the Plath compass in use.
25. L. McKinstry: *Hurricane, Victor of the Battle of Britain*, John Murray Great Britain, pp. 132-133 (2010).
26. German patent No. 474100 of 26 Mar 1929.
27. Konrad Knirim. *Militärühren*. ISBN 3-89355-232-4. Pomp, 2002. pp. 441. Cardboard horizontal sundial issued to German troops in North Africa.
28. R.J. Vinck: 'The Astro Compass', *NASS Compendium*, 10(3), 23 (Sept 2003). A brief explanation of usage.
29. www.knirim.de/rlmbhi.pdf A fine gallery and history of German WW II navigational and time-keeping instruments.
30. J.E. Morrison: *The Astrolabe*, Rehoboth Beach, (2006). pp. 313-319.
31. www.lend-lease.airforce.ru/english/articles/sheppard/hurricane/index.htm. This article describes the difficulties of using the magnetic compass at over 70° north.
32. Instruzione Sulla Bussola Solare Universale Mod 1 P.B.-1°. Coi Tipi Dell' Istituto Geografico Militare. Firenze. 1942-XX. A full paper on the Italian efforts and design from the Kaufman Sun Compass.

REFERENCE WITHOUT TEXT CALL:

www.enotes/topic/Long_Range_Desert_Group This is a good site for the history of Bagnold and the LRDG.

AUTHOR'S ADDRESS

sundials@sundials.co.za

www.sundials.co.za