The Buzzard Coulee Meteorite Fireball

Martin Beech
Campion College, The University of Regina, Regina, SK, Canada S4S 0A2

Introduction

The extremely bright fireball that presaged the arrival of the Buzzard Coulee meteorite first became luminous at UT 00:26:40, November 21, 2008. Lasting for about 6 seconds the fireball was probably observed by many thousands of eyewitnesses in the Canadian Prairie Provinces of Alberta, Saskatchewan and Manitoba. The appearance of the fireball generated almost unprecedented media attention (Beech, 2003), and several hundreds of eyewitnesses submitted reports on what they saw to the Canadian Fireball Reporting website (http://miac.uqac.ca/MIAC/fireball.php) – it is primarily an analysis of these data that we shall present here.

One week after the passage of the fireball, the first meteorites were successfully found by Dr. Alan Hildebrand (University of Calgary, Alberta) and Masters graduate student Ellen Milley on a frozen pond in Buzzard Coulee, located about 40 km southeast of Lloydminster, in Saskatchewan (UCPR Nov. 28, 2008). Subsequent ground searches have resulted in the recovery of more than one hundred meteorite fragments (figure 1) with masses ranging from just a few grams to 13.1 kg. The total collected mass to date is of order 50 kg. The meteorite has been identified as an H4 chondrite at the low end of the thermal alteration scale (UCPR Dec. 22, 2008). On-going analysis of the multiple video captures of the fireball (figure 2) will eventually result in an orbit being derived for the meteorite's parent body.

Figure 1: A modest sized specimen emerges from the Buzzard Coulee strewn field. The authors first find of the day on November 29th, 2008.

Figure 2. A single frame from a security camera video sequence captured at Biggar, Saskatchewan. The range to the fireball is of order 160 km. Image reproduced courtesy of R and D. Meger.

Infrasound detection data from instruments located in Manitoba, Ontario, Greenland, Washington and Utah provide an equivalent energy estimate for the fireball of 0.32 ± 0.09 kilotons of TNT (Peter Brown, University of Western Ontario, personal communication), suggestive of an initial entry mass of order 10 to 15 tonnes (UCPR Nov. 25, 2008). Figure 3 shows the light variations associated with the fireball and its sky glow as recorded at Campion College, The University of Regina (at a range of some 520 km). Rapid, short-duration light variations clearly indicate multiple fragmentation events occurring after the attainment of peak brightness, and a large terminal fragmentation event is apparent about 0.8 seconds after the time of peak brightness. To the radiometer's detection threshold of approximately magnitude -4, the event lasted for a total of 2.5 seconds. Previous calibration of the radiometer's response characteristics indicate that for a given count rate N, the equivalent stellar magnitude is approximately $m = -2.5\log(N) - 1.5$. Accordingly, the peak brightness count of $N = 6371$ indicates a maximum brightness of order magnitude -11. Since the fireball occurred very low on the horizon from Regina a significant brightness correction is indicated. The standard correction tables published by Dan Green (1992) indicate that for a location altitude of 500 meters (appropriate to that of Regina: altitude = 577 m) and a zenith angle of order 90 degrees a correction of some 9 magnitudes is required. This sizeable correction places the peak brightness at about magnitude -20; a magnitude comparable to that of the Sun ($m_V = -26.75$).

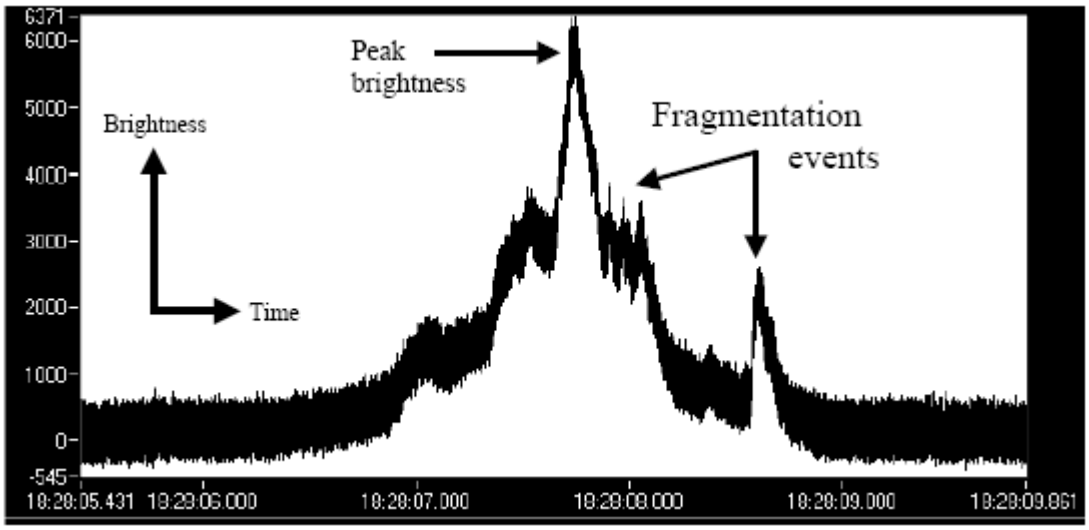

Figure 3. Radiometer recording of the Buzzard Coulee fireball from Campion College in Regina, Saskatchewan. From Regina the fireball was extremely low to the horizon and significant corrections are required to enumerate the peak brightness in stellar magnitudes.

Eyewitness reports

That the Buzzard Coulee meteorite fireball was a truly spectacular sight is easily gleaned from the general comments provided by the eyewitness reports: it "looked like a hole was burnt right through the ozone" wrote one observer from Edmonton, Alberta – giving a minds-eye image, although physically incorrect interpretation of the event. Another observer from Millet, Alberta commented, it looked like a "giant while ball … [which] disintegrated into black nothingness moments before it hit the Earth". From Dore Lake, Saskatchewan an eyewitness commented that the "whole western sky lit up as bright as day". Likewise another eyewitness located in The Pas, Manitoba commented that they saw an "orange color trail which illuminated the horizon somewhat like a sunset". And, finally, one eyewitness, who was driving through the town of Brooks, Alberta, wrote "I couldn't believe my eyeballs".

It is readily apparent from the email reports that all eyewitnesses struggled to accurately describe how bright the fireball was. This difficulty, of course, is hardly surprising given that it was at least as bright as magnitude -20. Comments concerning the brightness varied from "way brighter than the Moon", to "some sort of lightning storm", "like sunrise", "it lit up the area nearly as bright as the Sun", "like a white flare trailing golden sparkles", and, like "a welder's spark…. which lit up the sky as if it were daytime". While many eyewitnesses were fortunate enough to catch the entire display others experienced just a fleeting and peripheral glimpse of the fireball. Accordingly one eyewitness from Edmonton described the event as "a large, quick, bright flash of light", while another eyewitness from Kindersley, Saskatchewan, simply wrote that they saw a "hugh flash in the sky". The descriptions of the fireball's general appearance echo those given for its brightness: an observer from Hardisty, Alberta, commented that "the fireball

and tail appeared to consume most of the sky … around the head of the fireball I saw various colours which included orange, red and greens." Another eyewitness driving near Vermillion, Alberta described the display as being, "like a million lights turned on at once". Eyewitness estimates of the fireball's duration vary, of course, according to the individual viewing circumstances. Figure 4, shows the range of duration estimates. Clearly most observers place the duration somewhere between 2 and 5 seconds, although a good number of observes suggested times well in excess of 10 seconds; three observers even suggested that the fireball lasted for 30 seconds. While not articulated within their reports those observers indicating that the fireball duration was in excess of 10 seconds may well have been referring to the time over which they could see the fireball and its remnant train.

The various video captures of the fireball suggest a probable duration of 6 to perhaps 7 seconds. The video sequence captured with the all sky camera located at Campion College lasts for 2.5 seconds, but the early atmospheric and end flight stages are not recorded because of the excessive range (some 520 km) and atmospheric extinction. A video sequence captured by a police car while on patrol in Devon, Alberta, at a range of 350 km did capture the beginning phase of the fireball and shows a luminous trail lasting for some 4 seconds. The video sequence captured in Biggar, Saskatchewan (figure 2), at a range of order 160 km, shows the fireball approaching the horizon and last for 5 seconds. The longest video sequence lasts for about 6 seconds and was captured from a 10th floor high rise building in Edmonton, Alberta. In this latter case the very beginning of the fireball's luminous phase was missed but it was otherwise tracked all the way to the onset of dark flight. Interestingly, the Edmonton video sequence also indicates that three, and possibly more, very large fragments survived the ravages of atmospheric flight (figure 5). The largest Buzzard Coulee meteorite fragment found to date has a mass of 13.1 kg, and there is accordingly every reason to believe that several similar mass (if not more massive) meteorites have yet to be found in the strewn field.

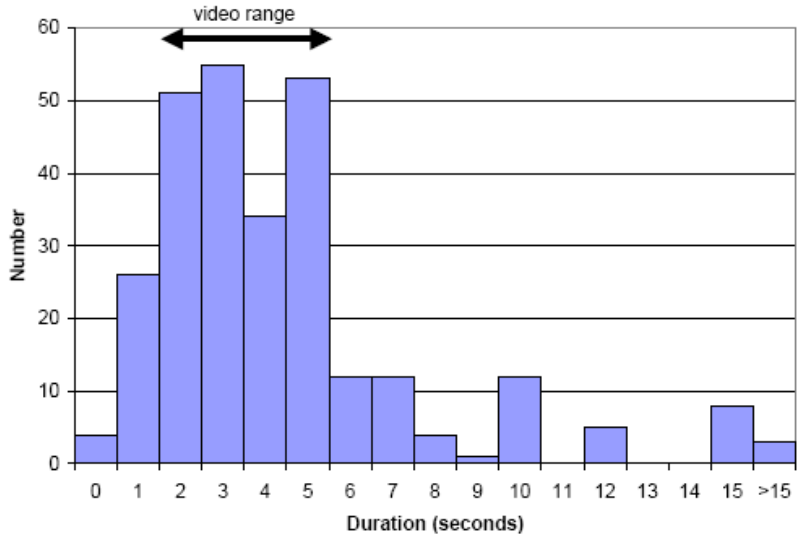

Figure 4: Eyewitness estimates of the fireball duration. The modal time estimate is 3 seconds. The arrowed horizontal line indicates the range in durations as revealed by video captures recorded at ranges varying from between 150 and 500 km.

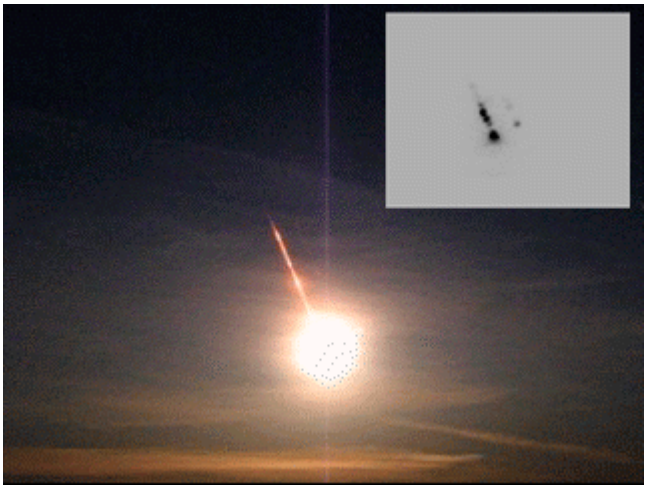

Figure 5: A single frame from the video sequence captured by Mr. Andrew Bartlett taken from his 10th floor apartment building window in Edmonton. The inset shows an enlarged portion of the fireball trail as seen in one of the final video frames. At least three distinct fragments can be seen in the inset image. Note that window reflections have caused a faint, parallel string of images to appear to the right of the actual trail. Image courtesy of A. Bartlett.

In total 424 email reports directly relating to the observation of the Buzzard Coulee fireball were received. The first eyewitness report arrived at the fireball reporting website within 15 minutes of the event having occurred, and over the ensuing 6 hours a further 84 reports were submitted. In the 24 hour interval from midnight November 20th to midnight November 21st (CST) an additional 242 eyewitness reports were received. Figure 6 shows that number of reports received during the time interval from November 20th (starting at 18:42 CST) to midnight November 30th (CST). A flurry of great initial activity is clearly present in the reporting distribution, with about one-third of all the reports being received within 24 hours of the event having taken place. A smattering of eyewitness reports were still coming-in, however, up to a week after the event occurred. The locations from which the various eyewitnesses saw the fireball are illustrated in figure 7.

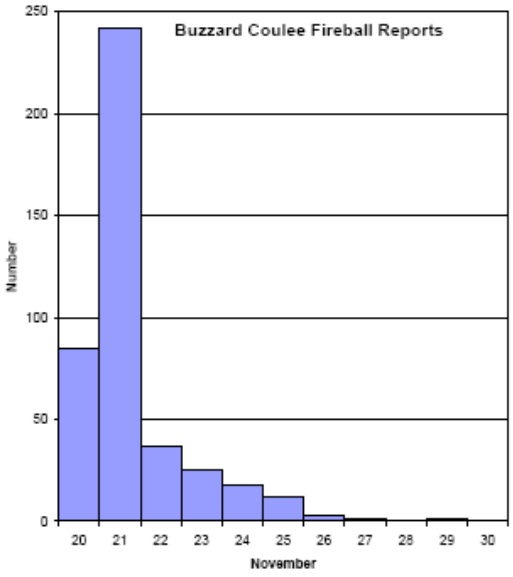

Figure 6. Number of eyewitness reports relating to the Buzzard Coulee meteorite fireball received per day from November 20th to midnight November 30th (CST).

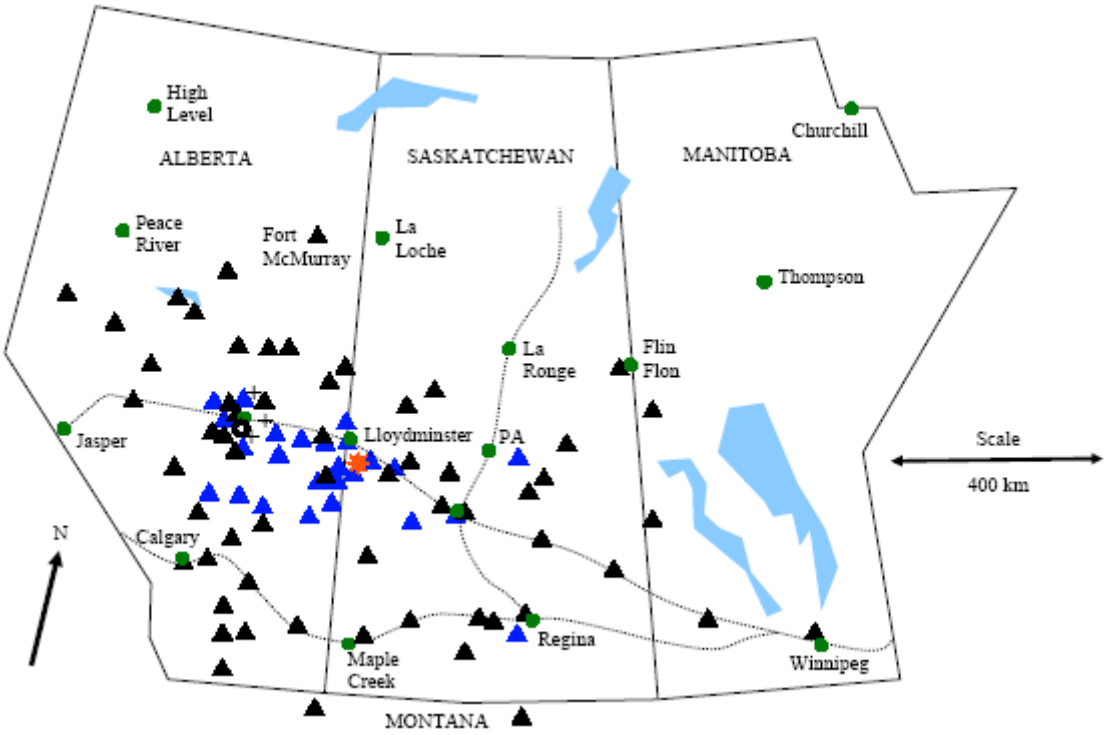

Figure 7. The spatial distribution of observers who reported seeing the Buzzard Coulee meteorite fireball. We have not attempted to indicate the location of every eyewitness since many were received from the same or very similar locations - a total of 84 reports (indeed, about 20% of the total number), for example, were submitted from Edmonton, Alberta, alone.

Within Canada, the fireball was seen from as far away as Winnipeg, Manitoba (at a range of some 930 km), but the majority of eyewitness reports were received from residents living in Alberta – the fireball occurred there at 17:30 MST and accordingly was witnessed by many people traveling home from work. Indeed 172 reports (40.6 % of the total) were received from people indicating that they were sitting within a motor vehicle. Five reports were received from pilots who witnessed the fireball while their aircraft were in flight; one report was received from a passenger in an aircraft that was in the process of taking off from Edmonton International Airport. Relatively few reports concerning the fireball were received from observers north of latitude 55^{o} N – this is most probably due to a combination of cloud cover and the low population density in northern Alberta and Saskatchewan. Observations of the fireball were also reported from eyewitnesses in the

northern United States. From Scobey, Montana, for example, at a range of order 600 km, one observer reported that they "saw a flash like lightning", while other observers near Kremlin, Montana reported that the "main ball was accompanied by numerous smaller fragments around it" (recall figure 5 – inset).

In addition to the Buzzard Coulee fireball, email reports relating to at least eight other fireballs appearing on the night of November 20th were received. Indeed, this caused some considerable confusion to a number of eyewitnesses and media reporters. The various emails received indicate that at least two bright fireballs were seen from the Pacific Coast of British Columbia and northern Californian during the evening of November 20th. A bright fireball was also seen over southern Ontario, and Illinois. Another bright fireball was reported from New Brunswick, Canada as well as locations within New Hampshire, New Jersey and Vermont. A very bright, detonating fireball was seen over Florida, and yet another bright fireball was reported from Texas, Arkansas, Oklahoma and Louisiana. With respect to this latter event, an email report was received from a radio station in Little Rock, Arkansas indicating that they had received some 10 calls from listeners concerned about bright flashes that had been seen in the sky. Email reports of other fireballs seen on the night of November 20th were also received from as far a field as the island of Bermuda, and the Orkney Islands in Scotland.

Sound reports and oddities

In addition to providing a once in a lifetime visual display some 59 (14 % of the total) eyewitness reports of the Buzzard Coulee fireball indicated the presence of associated sounds. This percentage is actually fairly typical with respect to similar such bright fireball events (Beech, 2004). Three eyewitness reported sensing strange smells, one observer reported that his dog was spooked and greatly agitated just before and after the passage of the fireball, while another observer reported feeling heat upon the side of his face. Indeed, it was this sensation that caused the latter eyewitness to turn his head and thereafter see the fireball. The locations from which sound phenomena were reported are shown in figure 8. The larger ellipse in the figure indicates that sound phenomena were widely reported at ranges up to several hundred kilometers from the fireball's ground

path. Two observers in Avonlea, Saskatchewan (southwest of Regina) reported hearing a "staccato" sound from what would be a range of 500 km. Many observers in Edmonton (range 230 km) also reported hearing staccato, popping and sharp sounds at the same time that the fireball cut across their eastern horizon. Only electrophonic (also called anomalous) sounds are likely to be heard at such distances (Keay, 1980; Romig and Lamar, 1963). What are reasonably interpreted as electrophonic sounds were reported by people who were driving as well as observers who were out hunting and or simply walking in the street. Interestingly there are reports from five drivers who had their radios on, saw the fireball but heard no sounds. Likewise, two eyewitnesses were having telephone conversations, four were at home watching television and one was using a computer when the light from fireball was observed – and yet they heard no sounds. These observations are consistent with the argument that electrophonic sounds are generated via the propagation of very long wavelength radiation derived from a narrow bandwidth region in the electromagnetic spectrum (Keay, 1980; Beech, Brown and Jones, 1995). The three eyewitness reports of sensing odd smells, the spooked dog and the eyewitness who felt a heat sensation may also be related to the electrophonic phenomena, and similar such experiences have been reported in relation to the passage of other very bright fireballs (Romig and Lamar, 1963; Kaznev, 1994).

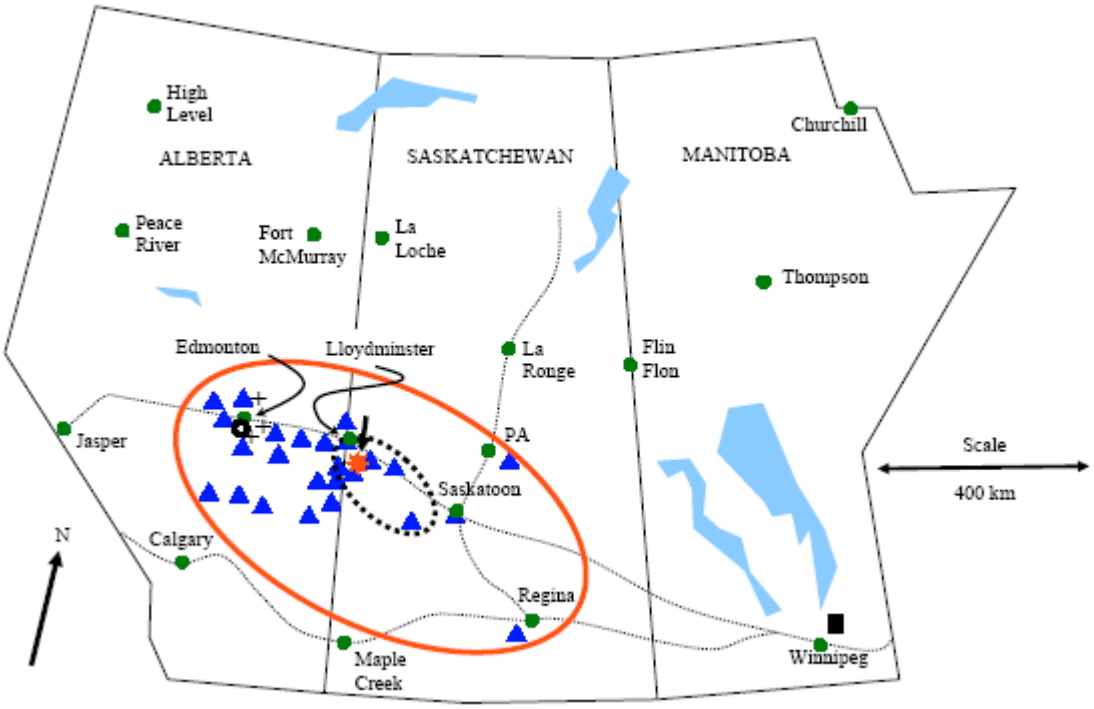

Figure 8: The distribution of eyewitnesses that reported sounds associated with the Buzzard Coulee fireball. Many of the triangles indicate multiple eyewitness locations. The smaller ellipse indicates the region in which observers reported sonic booms, while the larger ellipse corresponds to the zone in which electrophonic sounds were experienced. The crosses indicate the location of the three observers reporting smells, the circle indicates the location of the one observer who reported a heat sensation. The filled square indicates the site of the Lac du Bonnet, Manitoba, infrasound detector. The short arrow to the east of Lloydminster indicates the approximate north-south ground path of the fireball which entered Earth's atmosphere at a very steep angle (estimated to be ~60 degrees to the horizon).

Closer to the ground path of the fireball and the eventual strewn field, at ranges of perhaps 50 km and less, many eyewitnesses reported hearing sharp crackling sounds. These sounds are most probably associated with the arrival of closely spaced sonic booms – the result of multiple fragmentation events. Sonic booms and rumbling sounds were only reported by those eyewitnesses located at ranges less than about 150 km. At

Biggar, Saskatchewan (recall figure 2), a distinct rolling thunder-like sound was heard about five minute after the fireball. In the Lloydminster area, in contrast, with ranges of order 50 – 100 km, various eyewitnesses reported very loud sonic booms and seismic related phenomena: “it sounded like a large freight train” commented one observer. Other eyewitnesses described the sounds as being “like a helicopter overhead”, a “large rumbling sound”, “like a jet engine” and that it “crackled like a rocket”. Several eyewitnesses in the Lloydminster area also reported that their houses shook; one eyewitness even commented that they ran upstairs thinking a tree had fallen on their house. Perhaps the most remarkable sound report is that received from an observer located in the hamlet of Lone Rock, Saskatchewan. Their somewhat laconic report reads, “Saw the flash. Lit up the sky to daylight brightness. Stepped out on deck on south side of house. Looking almost directly up I saw the fireball and flame streak. At the same time heard a high pitched whistle with throbbing base [sic] sound. Windows rattled in the house…” In this case it is clear that the observer actually heard the rotating meteorite fragments (at that time in their dark flight phase) passing overhead. Indeed, Lone Rock is located less than 10 km away from where the first meteorite fragments were eventually found.

The Buzzard Coulee meteorite strewn field is situated within mostly open pasture land, but no animals were reported injured during the fall, and nor were there any reports of buildings being damaged. Some eyewitnesses did report having near motoring accidents, however, as a result of witnessing the fireball. One driver near to the town of Ohaton, Alberta, commented, “saw a spark in my windshield [which] looked and felt like a train coming on top of my windshield - I put on the brakes and skidded to a stop”. Another driver traveling near Elk Island National Park, Alberta, commented that upon seeing the fireball they “made an auto response to the brake”.

Many eyewitnesses were deceived by the appearance of the fireball to think that it must have produced meteorites close to their viewing locations. Indeed, several observers reported that they actually set out to search for the “crash site”, and were incredulous of the fact that the suggested meteorite search area was many tens, if not hundreds of

kilometers away from where they were situated. In addition, two eyewitnesses from near Edgley, Saskatchewan (located to the east of Regina) who saw the sky flashes associated with the fireball set out to find the "impact crater", and by chance came across a field in which a farmer was burning-off the remnants of an old building. Thinking that this was the devastation associated with the meteorite fall they informed the local media, who sent out a camera crew to record the story.

End note

The analysis of the Buzzard Coulee meteorite fall and its associated fireball has only just begun, and further laboratory analysis and ground-work will, without doubt, continue well into the foreseeable future (UCPR Dec. 22, 2008; UCPR Dec.18, 2008). The orbit of the parent body has yet to be annotated, the cosmic ray age of the meteorite's parent body has yet to be determined, the light-curve and atmospheric flight have yet to be studied in detail, the meteorite's petrology has yet to be fully understood, and the extent of the strewn field and the total fall mass have yet to be enumerated. The work, however, has begun, and interesting times do indeed lie ahead for the investigation of this latest Canadian meteorite fall.

References

Beech, M. 2003. The Millman fireball archive. *Journal of the Royal Astronomical Society of Canada*, **97**, 71-77.

Beech, M. 2004. The Millman fireball archive II: Sound reports. *Journal of the Royal Astronomical Society of Canada*, **98**, 34-41.

Beech, M., Brown, P., and Jones, J. 1995. VLF Detection of fireballs. *Earth, Moon and Planets*, **68**, 181–188.

Green, D. W. E. 1992. Magnitude corrections for atmospheric extinction. *International Comet Quarterly*, **14**, 55-59. See also: http://www.cfa.harvard.edu/icq/ICQExtinct.html.

Kaznev, V. Yu. 1994. Observational characteristics of electrophonic bolides: statistical analysis. *Solar System Research*, **28**, 49-60.

Keay, C. S. L. 1980. Anomalous sounds from the entry of meteor fireballs. *Science*, **210**, 11-15.

Romig, M. F., and Lamar, D. L. 1963. Anomalous sounds and electromagnetic effects associated with fireball entry. The Rand Corporation, RM-3724-ARPA.

UCPR, Nov. 25, 2008. Meteorite search update: 10 tonne rock responsible for fireball. University of Calgary press release: http://www.ucalgary.ca/news/November2008/meteorite.

UCPR, Nov. 28, 2008. Meteorite field found in Saskatchewan. University of Calgary press release: http://www.ucalgary.ca/news/november2008/meteorite-found-advisory.

UCPR, Dec. 18, 2008. Meteorites on display. University of Calgary press release: http://www.ucalgary.ca/news/utoday/dec18-08/meteorites.

UCPR, Dec. 22, 2008. Meteorite bounty on track for Canadian record. University of Calgary Press releases: http://www.ucalgary.ca/news/December2008/meteoriterecord.