

## **Hunterston #1 DDH: Velocity Survey.**

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### **Aim**

The aim of the velocity survey was to use a downhole sonde (Fournier, 2000) to acquire velocity data at multiple levels in the Hunterston #1 DDH. The data was acquired at or as near as possible to formation boundaries (identified from core), therefore the resultant data represents the velocities across those formations. This data will then be used to as a means to convert between depth and time, enabling the formation boundaries to be plotted in time, onto seismic sections acquired adjacent to the Hunterston #1 DDH. Velocity data can also be applied to other drillholes with the same stratigraphy enabling formation boundaries to be plotted onto other seismic sections in the Tasmania Basin Seismic Survey. The accurate positioning of these formation boundaries on the seismic sections will greatly improve the accuracy of the interpretation.

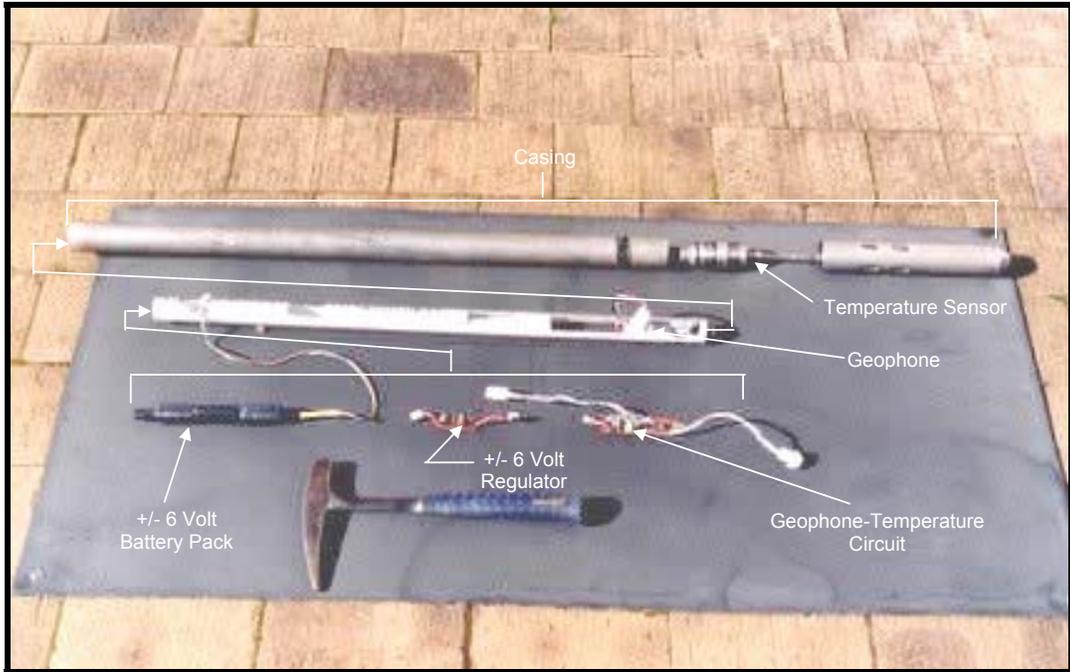
### **Equipment**

The system used to conduct the survey was developed by Patrick Fournier as part of an Honours thesis at the University of Tasmania (Fournier, 2000). The system consists of two main elements; a sonde containing a temperature sensor, a geophone, their associated electronics and a power supply (Figure 1) and a flat top trailer on which rides 1000m of communication cable labelled every 25 metres starting at the tail of the sonde and attached to a 12 VDC winch, 1000m of strength cable running through a counter (Figure 2). Seismic energy was provided by Powergel using zero delay detonators, the seismic data was recorded with a Geometrics ES-1225 seismograph the records then downloaded onto a laptop computer using *Seisview*<sup>TM</sup> seismic refraction interpretation software.

### **Procedure**

#### **Data Acquisition:**

Cracking the drill rods at the collar allowed the sonde to be lowered through the rods into the open well. The trailer with the communications and strength cable was positioned adjacent to the well, the cables running via a set of pulleys slung from the derrick, guiding the cables into the well. The energy source was fired 50m from and 6m below the well collar in a pond, which provided good coupling between the seismic energy source and the ground.



**Figure 1:** Downhole Sonde.



**Figure 2:** Seismic sonde cable trailer and seismograph.

The sonde was lowered into the well, the distance below the collar calculated to the nearest metre by using the labels on the cable in concert with the counter on the strength cable. When the desired depth was reached, the cables were clamped at the top of the well and the tension between the well collar and cable reels released to reduce the any noise induced by the cables.

The seismograph would then be connected to the communications cable (this connection could not be maintained when the cable reel was moving during raising or lowering); the charge would then be readied for the shot. When the shot was fired a signal would be generated to trigger the seismograph. On completion of the shot, the seismograph would be checked to ensure the data was recorded successfully, the data downloaded onto a laptop computer and the seismograph cleared and readied for the next shot. The cable connecting the seismograph to the communications cable would then be removed, the clamps at the collar removed and the sonde lowered to the position of the next shot, the above process then repeated for the next shot.

Shots were taken at varying intervals in the well to best ascertain the velocities across and within the formations identified in the Hunterston #1 DDH (Figure 3). Nine shots were taken in all, shot 1 was taken to ascertain the velocity of the weathering layer, shot 2 for the velocity in the Ferntree Mudstone, shots 3-6 to ascertain the variation in velocity variation in the Jurassic Dolerite, shot 7, 8 and 9 to ascertain the velocity of the Cascades Group, the Liffey Group and the Bundella correlate respectively.

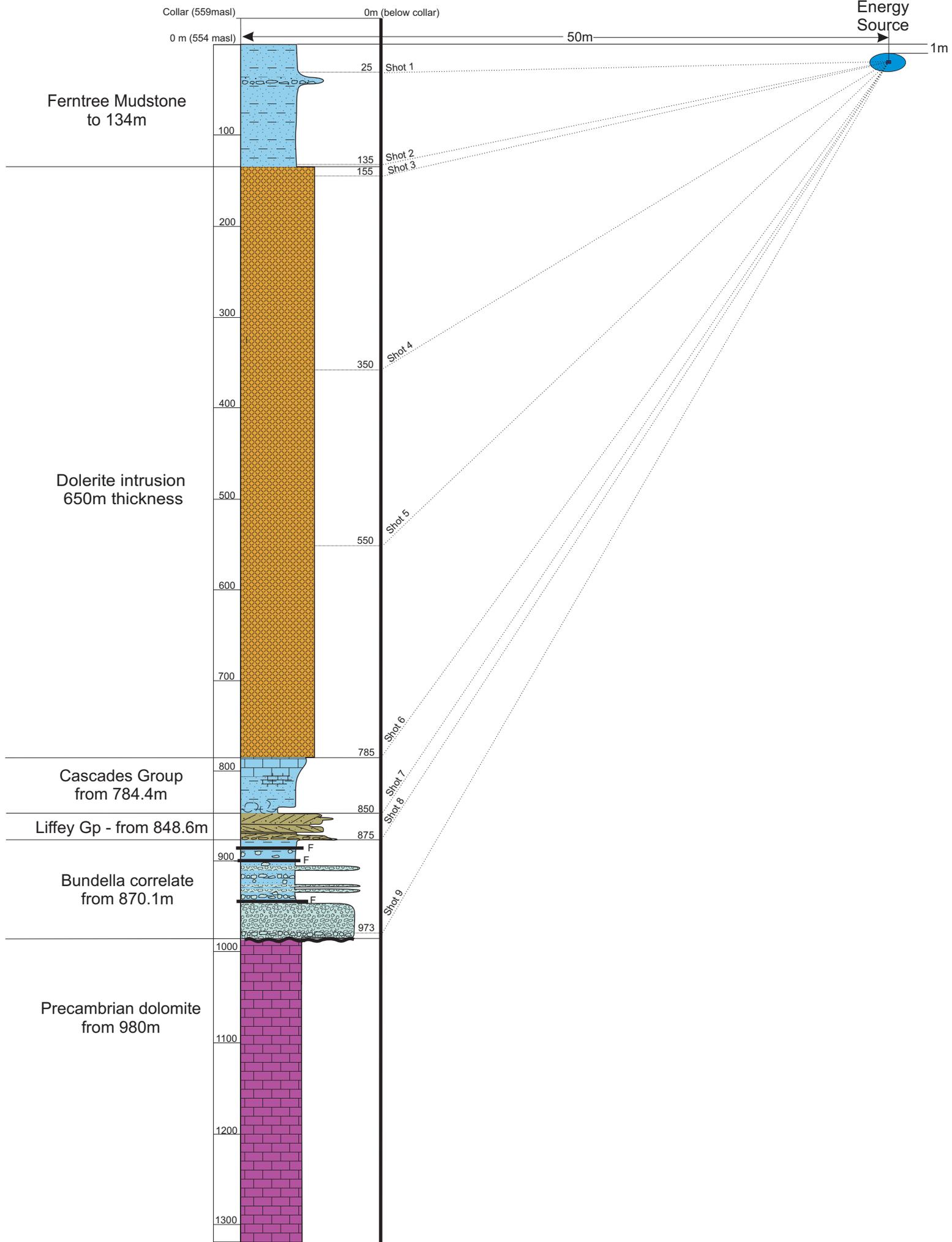
### **Interpretation:**

The data recorded by the seismograph and downloaded onto the laptop computer were the seismic energy arrival times at the geophone in the sonde (one-way times) (Figure 4). The initial arrivals of seismic energy or first breaks are the times required to calculate velocity. The first breaks for this data set are troughs; the times were picked as the first negative deflection of the signal into the first large trough of the seismic record (Figure 4).

Once the first brakes were picked and recorded the cumulative and interval velocities could be calculated using the equation (Table 1):

$$v=d/t \quad v = \text{velocity (m/s), } d = \text{distance (m) and } t = \text{time (seconds)} \quad \{\text{eqn. 1}\}$$

To calculate the interval velocity, the time and distance difference between an interval and all its preceding intervals had to be calculated so that only the time taken and the distance travelled through that particular interval were considered by the equation (Table 2).



**Figure 3:** Hunterston #1 DDH velocity survey shots and raypaths.

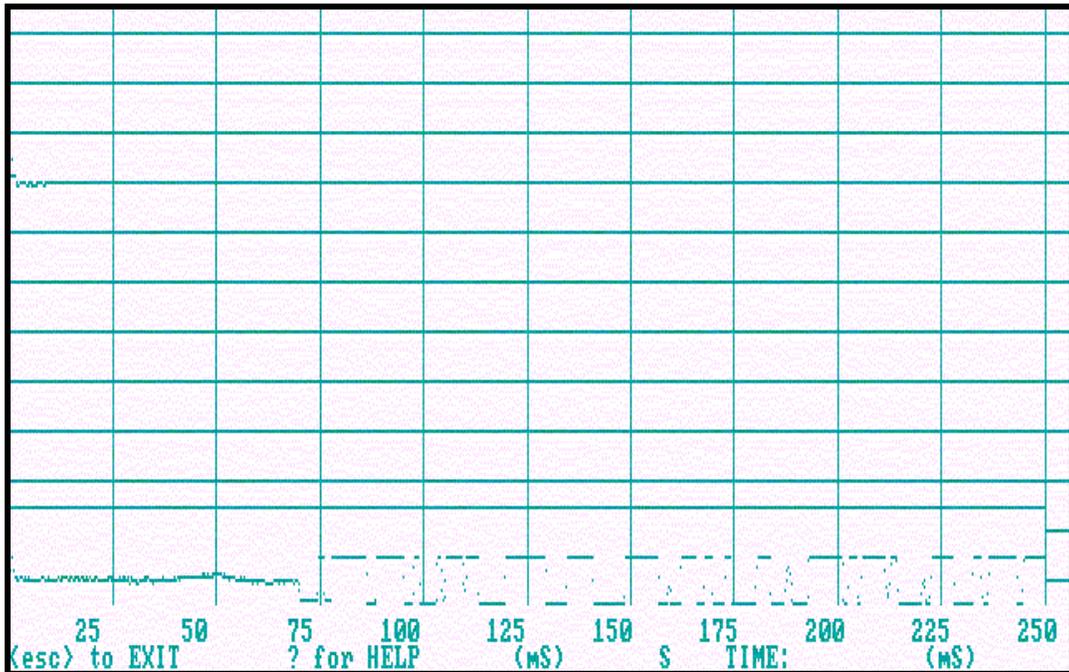


Figure 4: Seismic data record with first break for shot at 350m (below collar).

## Results

The results of the velocity survey are displayed in tables 1 and 2. Two interesting features are observed in the data. Firstly, that there is a considerable variation in velocity within the Jurassic dolerite, this variation was explored by Fournier (2000). Secondly, that the velocity of the Liffey Group is considerably lower than that of the surrounding strata which should result in a strong event corresponding to the top of the Liffey Group.

Fournier, P., 2000, The design of a Sonde used to measure Seismic Velocities and Temperature, Tasmania Basin. Honours (unpublished) thesis, University of Tasmania, Hobart, 91 p.

**Table 1:** Results of the Hunterston #1 DDH Velocity Survey.

<b>Hunterston #1 DDH - Velocity Survey</b>											
Collar Height: 5m Distance Collar-Source: 50m Elevation difference well-source: -1m											
Shot	Filename	Depth from Collar (m)	Depth below ground level (m) (referenced to source)	Distance shot-geophone (m)	1-way time (sec)	2-way time (sec)	Shot-geophone cumulative velocity	Distance difference (cumulative)	Time difference (cumulative)	Interval	Interval Velocity
1	hunt25d	25	19	53.48832	0.01700	0.03400	3146.37176	0.00000	0.00000	0-25 Weathered Layer	3146.37
2	hunt135a	135	129	138.35100	0.03525	0.07050	3924.85115	20.37728	0.00648	25-135 Ferntree Mudstone	4100.07
3	hunt155a	155	149	157.16552	0.03875	0.07750	4055.88433	136.06948	0.03467	135-155 Top Dolerite	5168.95
4	hunt350a	350	344	347.61473	0.06975	0.13950	4983.72372	150.56522	0.03712	155-350 Intra-Dolerite 1	6039.42
5	hunt550a	550	544	546.29296	0.09725	0.19450	5617.40835	345.44996	0.06932	350-550 Intra-Dolerite 2	7189.82
6	hunt785a	785	779	780.60297	0.13300	0.26600	5869.19528	545.11941	0.09704	550-785 Base Dolerite	6548.68
7	hunt850b	850	844	845.47975	0.14550	0.29100	5810.85736	780.36578	0.13296	785-850 Cascades Gp	5192.33
8	hunt875a	875	869	870.43725	0.15150	0.30300	5745.46037	845.39590	0.14549	850-875 Liffey Gp	4163.55
9	hunt973a	973	967	968.29179	0.17400	0.34800	5564.89537	870.16088	0.15145	875-973 Bundella	4352.07

Table 2: Interval velocity calculations, Hunterston #1 DDH.

Interval Velocity Calculations - Hunterston #1 DDH																							
Interval 0-25m (Weathered Layer)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	Velocity (D <sub>1</sub> ) (Interval Velocity)																	
50	19	53.48831648	0.01700	69.19320899	53.48831648	3146.371558																	
Interval 25-135 (Ferntree Mudstone)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	D <sub>2</sub>	Time Difference (t <sub>1</sub> =d <sub>1</sub> /v)	Velocity (D <sub>2</sub> ) (Interval Velocity)															
50	129	138.3510029	0.03525	21.18617644	20.3772795	117.9737234	0.00647644	4100.073613															
Interval 135-155 (Top Dolerite)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	Time Difference (t <sub>1</sub> =d <sub>1</sub> /v)	Time Difference (t <sub>2</sub> =d <sub>2</sub> /v)	Total Time Difference	Velocity (D <sub>3</sub> ) (Interval Velocity)												
50	149	157.1655178	0.03875	18.55023193	20.04124053	116.0282347	21.0960427	0.006369636	0.028299061	0.034668697	5168.947936												
Interval 155-350 (Intra Dolerite-1)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	Time Difference (t <sub>1</sub> =d <sub>1</sub> /v)	Time Difference (t <sub>2</sub> =d <sub>2</sub> /v)	Time Difference (t <sub>3</sub> =d <sub>3</sub> /v)	Total Time Difference	Velocity (D <sub>4</sub> ) (Interval Velocity)										
50	344	347.6147293	0.06975	8.269961587	19.19965074	111.1558727	20.2101587	197.0490471	0.006102156	0.027110702	0.003909917	0.03712278	6039.405684										
Interval 350-550 (Intra Dolerite-2)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	D <sub>5</sub>	Time Difference (t <sub>1</sub> =d <sub>1</sub> /v)	Time Difference (t <sub>2</sub> =d <sub>2</sub> /v)	Time Difference (t <sub>3</sub> =d <sub>3</sub> /v)	Time Difference (t <sub>4</sub> =d <sub>4</sub> /v)	Total Time Difference	Velocity (D <sub>5</sub> ) (Interval Velocity)								
50	544	546.2929617	0.09725	5.251401822	19.08008506	110.4636503	20.0843001	195.8219256	200.8430006	0.006064155	0.02694187	0.00388557	0.032424039	0.069315632	7189.817338								
Interval 550-785 (Base Dolerite)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	D <sub>5</sub>	D <sub>6</sub>	Time Difference (t <sub>1</sub> =d <sub>1</sub> /v)	Time Difference (t <sub>2</sub> =d <sub>2</sub> /v)	Time Difference (t <sub>3</sub> =d <sub>3</sub> /v)	Time Difference (t <sub>4</sub> =d <sub>4</sub> /v)	Time Difference (t <sub>5</sub> =d <sub>5</sub> /v)	Total Time Difference	Velocity (D <sub>6</sub> ) (Interval Velocity)						
50	779	780.6029721	0.13300	3.672483507	19.03909688	110.2263504	20.0411546	195.4012574	200.4115461	235.4835667	0.006051128	0.02688399	0.003877221	0.032354385	0.027874359	0.097041086	6548.684019						
Interval 785-850 (Cascades Group)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	D <sub>5</sub>	D <sub>6</sub>	D <sub>7</sub>	Time Difference (t <sub>1</sub> =d <sub>1</sub> /v)	Time Difference (t <sub>2</sub> =d <sub>2</sub> /v)	Time Difference (t <sub>3</sub> =d <sub>3</sub> /v)	Time Difference (t <sub>4</sub> =d <sub>4</sub> /v)	Time Difference (t <sub>5</sub> =d <sub>5</sub> /v)	Time Difference (t <sub>6</sub> =d <sub>6</sub> /v)	Total Time Difference	Velocity (D <sub>7</sub> ) (Interval Velocity)				
50	844	845.4797455	0.14550	3.39033722	19.03331181	110.1928578	20.0350651	195.3418843	200.3506506	235.4120144	65.11396144	0.00604929	0.026875824	0.003876043	0.032344554	0.027865889	0.035947988	0.132959588	5192.33017				
Interval 850-875 (Liffey Group)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	D <sub>5</sub>	D <sub>6</sub>	D <sub>7</sub>	D <sub>8</sub>	Time Difference (t <sub>1</sub> =d <sub>1</sub> /v)	Time Difference (t <sub>2</sub> =d <sub>2</sub> /v)	Time Difference (t <sub>3</sub> =d <sub>3</sub> /v)	Time Difference (t <sub>4</sub> =d <sub>4</sub> /v)	Time Difference (t <sub>5</sub> =d <sub>5</sub> /v)	Time Difference (t <sub>6</sub> =d <sub>6</sub> /v)	Time Difference (t <sub>7</sub> =d <sub>7</sub> /v)	Total Time Difference	Velocity (D <sub>8</sub> ) (Interval Velocity)		
50	869	870.4372464	0.15150	3.293019443	19.03142426	110.1819299	20.0330782	195.3225121	200.3307817	235.3886685	65.10750405	25.0413477	0.006048689	0.026873159	0.003875659	0.032341347	0.027863125	0.035944423	0.012539169	0.145485571	4163.545096		
Interval 875-973 (Bundella Correlate)																							
Hole-source distance	Depth (m) (referenced to source elevation)	Source-geophone distance	1-way time (sec)	Angle 'a' (Degrees)	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	D <sub>5</sub>	D <sub>6</sub>	D <sub>7</sub>	D <sub>8</sub>	D <sub>9</sub>	Time Difference (t <sub>1</sub> =d <sub>1</sub> /v)	Time Difference (t <sub>2</sub> =d <sub>2</sub> /v)	Time Difference (t <sub>3</sub> =d <sub>3</sub> /v)	Time Difference (t <sub>4</sub> =d <sub>4</sub> /v)	Time Difference (t <sub>5</sub> =d <sub>5</sub> /v)	Time Difference (t <sub>6</sub> =d <sub>6</sub> /v)	Time Difference (t <sub>7</sub> =d <sub>7</sub> /v)	Time Difference (t <sub>8</sub> =d <sub>8</sub> /v)	Total Time Difference	Velocity (D <sub>9</sub> ) (Interval Velocity)
50	967	968.2917949	0.17400	2.959917289	19.0253817	110.1469467	20.0267176	195.2604964	200.2671758	235.3139315	65.08683213	25.033397	98.13091613	0.006046769	0.026864627	0.003874428	0.032331078	0.027854279	0.03593301	0.012535187	0.00601252	0.151451898	4352.069919