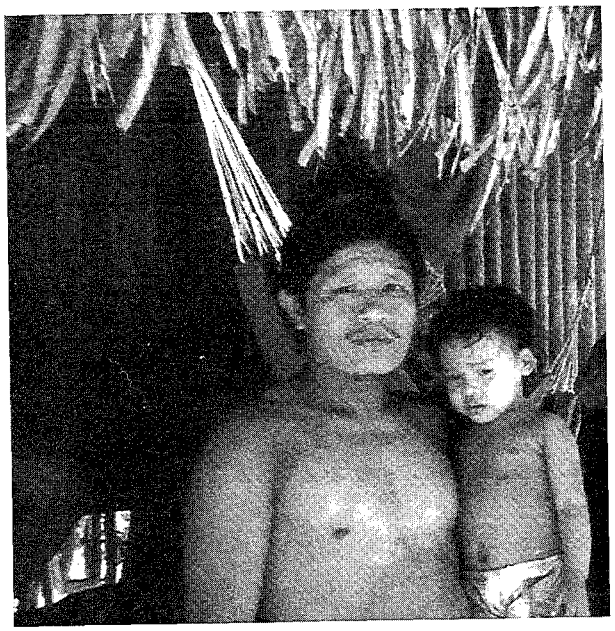

Figure 2.4 A Banawa speaker with his son.

it is useful to have a reminder that speaker 3 was the one shown in figure 2.4, who was carrying his small son.

2.2 Basic Palatography

Video cameras are helpful for recording movements of the lips and changes in jaw position, but they are of little help in telling us what part of the tongue is involved in an articulation and where the articulation is made on the roof of the mouth. The best way of recording this kind of data in the field (or in a simple laboratory set-up) is by means of palatography, a nineteenth-century technique that has now been developed so that it is capable of providing a great deal of information on tongue gestures.

Fieldwork palatography involves painting the tongue with a black substance, asking the speaker to say a word containing the articulation to be studied, and then observing where the black substance has been transferred onto the roof of the mouth. By putting a mirror into the

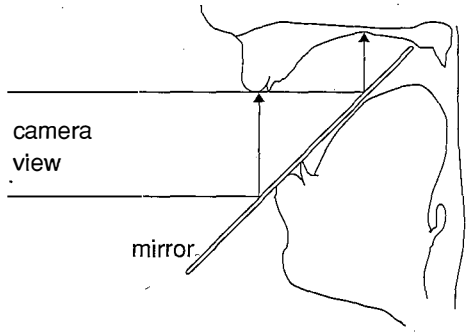

Figure 2.5 A system for photographing the roof of the mouth. The arrows show how (ideally) the view from the camera is directly up into the roof of the mouth.

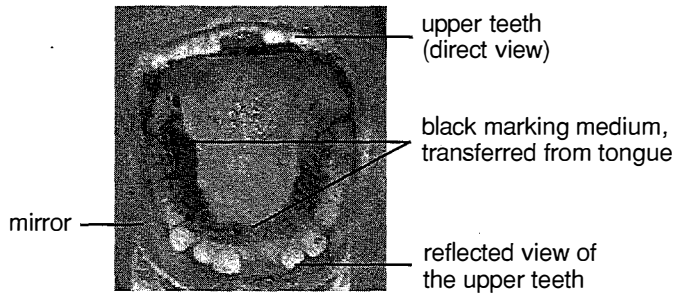

Figure 2.6 Palatogram of an Arrernte **t**. (Photograph by Victoria Anderson.)

mouth you can see (and photograph) the whole of the upper surface as illustrated in figure 2.5.

Figure 2.6 shows a photograph using this system, taken by Victoria Anderson as part of her fieldwork on Arrernte, an aboriginal language of Australia. The speaker's upper teeth are at the top of the picture. Below them, reflected in the mirror, is a view of the roof of the mouth, with the inside of the upper teeth being at the bottom of the picture. The speaker had had his tongue painted before saying a word containing an alveolar stop. The marking medium has been transferred to an area all the way around the molar teeth and across the alveolar ridge behind the upper front teeth (one of which is missing). This palatogram does not provide any information on the movements of the tongue, but we can see where in the mouth the stop was made.

The best marking medium is a mixture of equal parts olive oil and powdered charcoal. Powdered charcoal is completely tasteless and available from a pharmacist (it is used in medicines for flatulence). Any edible cooking oil will do. Paint the mixture on the part of the tongue that is likely to be used in the articulation, using a thick paintbrush. Remember that you don't know exactly what part of the tongue will be used in a particular articulation, and it is better to cover more than less. Be sure to go far enough back. You may have to paint not only the tip of the tongue but also the underside of the tip if there is any chance of a retroflex articulation being used.

Tell the speaker to relax and not swallow after the tongue has been painted. You want a natural pronunciation of the word, which most speakers can achieve once they have found that the mixture in their mouth is not unpleasant. Turn on the video camera so that you are recording everything, ask for the word to be spoken, put a mirror in the mouth and photograph the contact areas. You will need to shine a light into the mouth so that it can be photographed without any shadows. It is best to have a proper light attached to the camera, but even a flashlight is better than nothing. After each word has been photographed and the camera switched off, the mouth should be rinsed with water mixed with a little lemon juice so as to clean the upper surface. Then you can repeat the sequence with the next word: paint, relax, start video recording, speaker says the word, head back, mirror in the mouth, photograph.

Practice putting the mirror into the speaker's mouth before you do any painting of the tongue. Get the speaker to open the mouth as wide as possible. Then slip the mirror in so that its edge is behind the upper back teeth. Most speakers tilt their heads forwards at this moment and

Part of the joy of palatography is that it is possible to improvise and get some data without being too elaborate. At a party I once met a speaker of Basque who said that he distinguished a dental **s̪** from an alveolar **s**, a distinction I wanted to observe. I borrowed a small hand mirror, and made some charcoal by burning a piece of toast and scraping the black parts onto a flat surface. I ground them into a fine powder using a beer bottle as a rolling-pin. There was some olive oil in the kitchen to mix with the powder, and a cotton swab served as a paintbrush. Lacking a camera, I looked into his mouth and sketched what I could see. An interesting evening's work. The beer was good, too.

do not open their mouths wide enough. You want the head tilted back, the mouth wide open and the jaw pulled back. Then you can place the mirror at an angle of 45° to the plane of the upper teeth, so that the camera sees a view equivalent to looking straight up at the roof of the mouth, as shown in figure 2.5. The mirror should be about 5 cm wide and 15 cm long. A local glassworks can cut and bevel the edges of a mirror of this sort.

Making palatographic investigations requires a great deal of sensitivity to local customs. In many parts of Asia it is not appropriate for a man to place his hand on the top of a young woman's head. When putting a mirror into someone's mouth, make sure that you ask permission to steady the head with your other hand before beginning. It is always helpful to keep a polite distance away from the speaker. With a video camera and a zoom lens it is possible to take a picture of just the mirror in the mouth from a meter or so away, which speakers may find easier than having the photographer too close.

As with any instrumental procedure, you should demonstrate the whole procedure on yourself first. You can paint your own tongue quite easily, using a mirror. You can then relax, say a word, put the mirror into your mouth and let the speaker see the roof of your mouth. Make it clear that you have your own paintbrush, and that you have a separate paintbrush and a cleaned mirror for each speaker. I use a number of different color paintbrushes, cheap ones made for children rather than artists. I also pour a little of the oil and charcoal mixture into a saucer for each speaker so that they see that each paintbrush is dipped into a separate container. You must be careful with the black oil and charcoal mixture. It stains clothes easily, so it is best to put a towel or old shirt around the speaker. You should also make sure that the speaker sees that the mirrors have been thoroughly cleaned and stored in a sterilizing solution.

The words used in a palatographic investigation have to be carefully chosen. Palatography records the contacts that have been made in the whole word. When investigating the difference between English **s** and **ʃ**, it is no good looking at words like *sin* and *shin*. The contact for the **n** at the end of the word will obscure the contacts in the **s** and **ʃ**. A more suitable pair would be *sip* and *ship*. You need to search for words that have only the consonants you are interested in, or in which the only other consonants are bilabials or glottal stops. Sometimes this is not possible and you have to use a word containing a velar consonant. This may not be too bad if you are investigating dental consonants,

> Indians are very quick to notice if something that has been in one person's mouth is then dipped into a common pot. An Indian friend once told me how horrified he was the first time he went to dinner in an American household. His host was making soup. Every now and then she would taste it to see if it needed more seasoning – and then put the spoon, which had been in her mouth, back into the pot. Despite his admiration for her, my Indian friend found it difficult to eat dinner.

but it probably will affect the tongue position. Also remember that vowel and consonant articulations interact. Don't compare words like *she* and *saw*, as the high front vowel of *she* will cause noticeable raising of the sides of the tongue in comparison with *saw*. As we noted in the first chapter, always try to investigate minimal pairs, like *she* and *sea*, or *Shaw* and *saw*.

We usually want to know not only what part of the roof of the mouth is involved in the investigation, but also what part of the tongue has been used. We can get this information by reversing the process. Paint the roof of the mouth. Get the speaker to relax with the mouth slightly open (so that you can see that the tongue is not touching the roof of the mouth), start the video camera, and ask the speaker to say the word and then open the mouth and let the tongue lie in a neutral position on the lower lip (this requires a little practice). After the photograph has been taken, the speaker should thoroughly cleanse the tongue, perhaps using water with a little lemon juice in it, and wipe it with a paper towel or a cloth. It is much more difficult to clean the tongue than the roof of the mouth.

Photographs of the tongue made in this way are called linguograms. They are never likely to be as comparable as photographs of the roof of the mouth. It is difficult to place the tongue in exactly the same position after every utterance. But you can usually see whether it is the blade of the tongue that has been used for a laminal articulation or the tip (or even the underside of the tip) for an apical (or a retroflex) articulation. If you are investigating a potential retroflex articulation, the tip of the tongue will have to be raised before being photographed.

Figure 2.7 shows the palatogram of Arrernte **t** in figure 2.6, this time with its associated linguogram. Below it there is another palatogram and linguogram, in this case of Arrernte **t͡ʃ** spoken by the same speaker, and also photographed by Victoria Anderson. On both palatograms

an arbitrary grid has been drawn, based on the teeth and other anatomical landmarks, so that it is possible to compare one palatogram with another. In the palatogram of **t** in the upper part of the figure the tongue contact is on the forward part of the alveolar ridge, about 8 mm in front of the arbitrary reference line. The affricate **t͡ʃ** in the lower palatogram involved an articulatory contact that was further back, only about 4 mm from the reference line. The sides of the tongue made contact higher in the palate in the lower palatogram, as is shown by the fact that the untouched part of the horizontal reference line is shorter. Both these points can be measured with reference to the imposed grid.

It is difficult to make reliable measurements of the contacts on the tongue, shown in the linguograms on the right, as the shape of the tongue is not constant. The upper linguogram shows that the tip of the tongue is used to make the alveolar stop. In the lower picture, it is

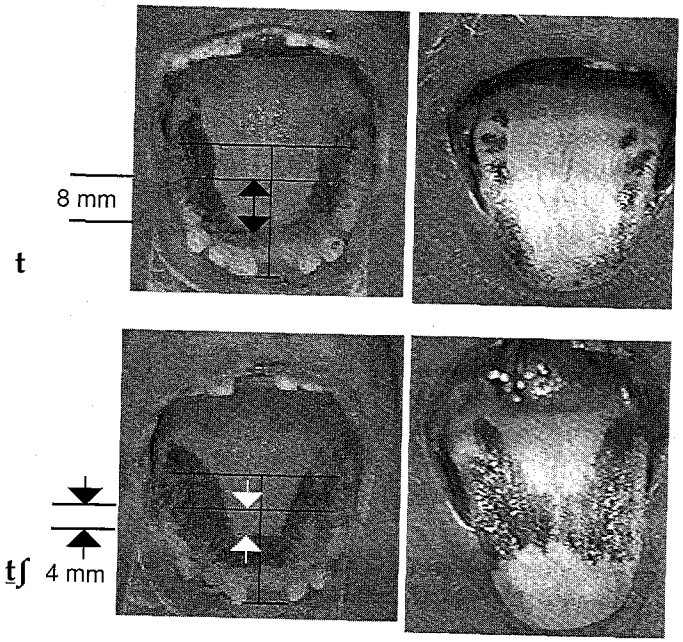

Figure 2.7 Palatograms and linguograms of an Arrernte speaker. The arrows indicate the distance between the back of the tongue contact near the center of the mouth and an arbitrary reference line. (Photographs by Victoria Anderson.)

apparent that the blade of the tongue is used for the palatoalveolar affricate, as the tip of the tongue is completely free of any of the black marking medium. But, because the shapes of the tongue in the two photographs are not the same, no measurements can be made. Pictures of the tongue can be compared only qualitatively, noting, for example, that one articulation involves the tip of the tongue and the other the posterior part of the blade.

Palatography is a fairly slow process. It can take an hour or more to photograph half a dozen words – two pictures for each word, one of the tongue and another of the roof of the mouth. Many speakers feel that that is enough for one session. Palatographic investigations should be planned carefully, allowing enough time to get sufficient words from as many speakers as possible. As with all phonetic studies, there will be more variation between speakers than within repetitions by the same speaker, so it is important to photograph a number of different people.

2.3 More Elaborate Palatography

Much more information can be gained from palatograms and linguograms if you know the shape of the roof of the mouth. Many sounds are distinguished, for example, by whether the tongue contacts the anterior or posterior part of the alveolar ridge, making the difference between an alveolar or retroflex sound. Photographs of the roof of the mouth, such as those on the left-hand side of figure 2.7, do not show exactly where the alveolar ridge is. For that you need an outline of the sagittal section, similar to that used in many diagrams of articulations. You can make this quite easily in the field using dental impression material. Figure 2.8 shows a speaker of !Xóõ having an impression of his mouth made in the Kalahari Desert.

Dental impression material is available from any dental supply house. I like the kind that changes color. It is purple when you mix it with water, pink when it is ready to be put into the mouth, and green when it is set, so that it can be taken out. You will also need a rubber mixing bowl and a spatula to mix the material thoroughly.

You do not need to make as full an impression as a dentist usually makes, using a tray that fits around both sides of the teeth. All we are interested in are the inner surfaces of the teeth. When you have mixed

Figure 2.8 Making an impression of the shape of the roof of the mouth in the Kalahari Desert.

the material according to the directions on the packet, take a large mound of it (about the amount recommended for making a full upper jaw impression) and place it on the mirror that you use when photographing the upper surface of the mouth. Ask the speaker to open the mouth and lean forward while you put the mirror in and press it against the lower surface of the upper teeth. You can get the speaker to bite down (gently) on the mirror, so that it is held firmly in place. Use sufficient material so that you get the shape of the whole of the oral cavity, including the soft palate. As the speaker has to breathe while the material is setting, the soft palate will be lowered 1–2 mm, but this will affect only the very back part of the roof of the mouth. Some of the material will be pushed out of the mouth. This excess material should be allowed to set around the upper lip, so that you can get this shape too. Speakers often drool a lot, which is why they should lean forward, but this does not affect the setting process. When the change of color indicates that the material is ready to be removed, rock the mirror slightly to loosen the material and then take it out.

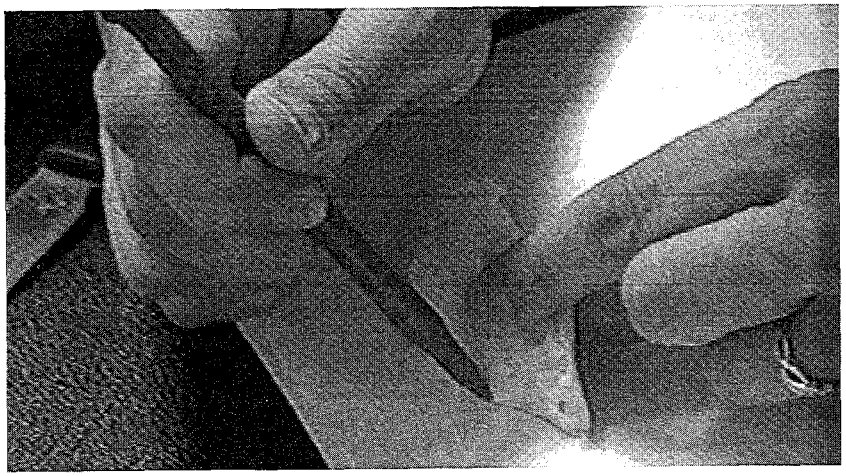

Figure 2.9 Victoria Anderson tracing an impression of the palate that has been cut in half so as to obtain part of a sagittal view of the speaker's vocal organs.

Making dental impressions is not difficult, but it does require practice. You have to be sure that the material goes right up to the roof of the mouth, that it goes far enough back, and that it covers all the inside surfaces of the teeth. Practice making impressions of your own mouth until you have made one that looks perfect.

If you simply want to know the shape of the mid-sagittal section of the palate, you can get this by cutting the impression material in half, and tracing the edges as shown in figure 2.9. However, you may want to make a more elaborate map of the palate, and for this purpose you should make a plaster cast of the impression material, so that you have a more permanent record of the speaker's mouth shape. Unless you keep it under water, the alginate impression material will soon shrink and lose its shape.

You can buy plaster for making a model of the speaker's palate from any hardware store. Get the hard, stone-like, type, which takes longer to set but is much more durable. Put water in your rubber mixing bowl and then add a little plaster (do it in this order) using a spatula to mix it thoroughly. Go on adding powder to the water until, after spatulating thoroughly, you have a thick, creamy mixture. Put the alginate impression into a small plastic bowl such as a margarine

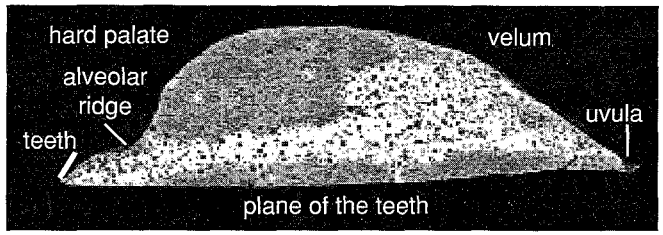

Figure 2.10 Part of a copy produced by placing half of an impression of the palate on the glass of a copy machine. Labels added later.

container, with the roof of the mouth uppermost, then pour the plaster onto it. Tap the bowl against the table continuously, so as to remove air bubbles (dental labs use a special vibrating table for this purpose). When the plaster is hard, take it out of the bowl, and remove the impression material. You will have a good permanent record of the speaker's palate. You can always trace the midline of this palate by putting additional impression material into it, letting it set, and then cutting it in half and tracing it as shown in figure 2.9. Alternatively, you can take the cut half of the impression and place it on the glass of a copying machine. This will produce an image such as that in figure 2.10 (without, of course, the labels, which I added later). This impression of my mouth was produced while the soft palate was lowered (so that I could breathe through my nose). It shows the shape of the roof of my mouth during a nasal rather than a stop.

Figure 2.11 shows three palatograms produced by a speaker of Scottish Gaelic. These palatograms differ from those we have been discussing in two ways. Firstly, instead of being painted with an oily black mixture that gets transferred onto the roof of the mouth, the tongue was kept clean. A black powder, a mixture of powdered charcoal and a little drinking chocolate (for flavor, and to keep the speaker salivating slightly) was sprayed onto the roof of the mouth. When a word was spoken, part of the powder was wiped away by the tongue contacting the roof of the mouth. So in this kind of palatogram, the black area is where the tongue has *not* touched. The principle is the same, but the black/non-black areas are reversed. The second point to note about these palatograms is that the mirror was not at an angle of 45° to the camera and the line of the upper teeth. As a result, the front-to-back dimension is lengthened in relation to the side-to-side

The photographs in figure 2.11 are part of a study by Fred Macaulay, a classmate of mine at Edinburgh University. Almost 45 years after taking this set of photographs of his own pronunciation of Gaelic he was kind enough to go to his local dentist and get a cast made, which he sent to me. He has lost a few teeth since making the palatograms, but the shape of his palate has not altered. Fred is a Gaelic speaker from South Uist in the Hebrides. He did not speak English at all until he went to school.

Figure 2.11 Palatograms of the Scottish Gaelic vowels as in the words **iː**, *i*, 'she, her', **uː**, *thu*, 'you' (sing.) and **ɯː**, *aodh*, 'liver'.

dimension. This was done deliberately so as to be able to record contact areas in the back of the mouth.

You can get even more information from these and other palatograms if you make the photographs life-size, so that they can be compared directly with a cast of the palate. A standard computer drawing program was used to transform the dimensions of the photographs in figure 2.11 independently. The side-to-side distance between the molar teeth on the two sides of the mouth was made the same as this distance on the cast of the speaker's mouth. Similarly, the front-to-back distance between the front teeth and a line between the posterior molars was made to be the same as on the cast. The resulting photographs are shown in figure 2.12.

The palatograms in figure 2.12 have white lines added, showing points that are 5, 10 and 12.5 mm down from the highest point of the palate. There are several techniques that can be used to find these

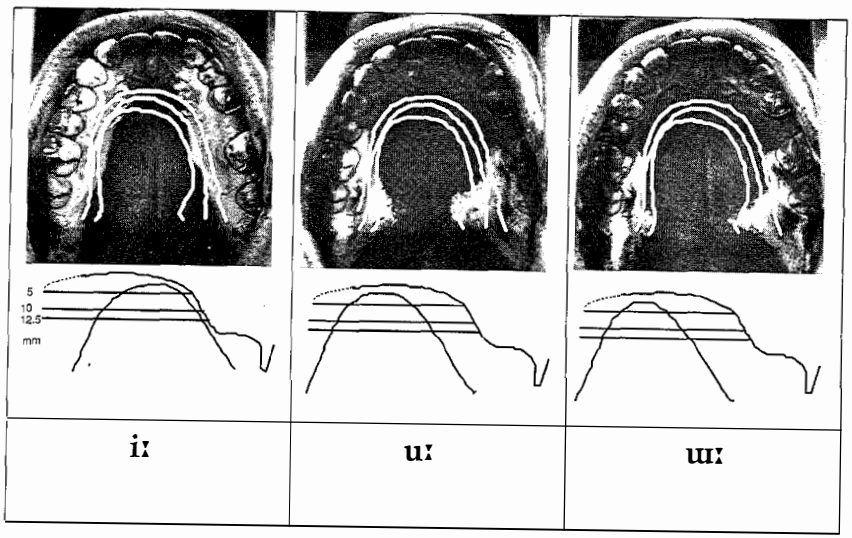

Figure 2.12 Re-scaled palatograms with contour lines superimposed and sagittal sections showing estimates of the tongue positions in the Gaelic vowels in figure 2.11.

contour lines representing the height of different parts of the roof of the mouth. One is to make an impression as discussed above, and then, instead of cutting it vertically as demonstrated in figure 2.9, make horizontal slices, each a few millimeters apart. Tracing around the slices provides the appropriate contours. A more accurate way is to fill a cast with a black liquid, first to a depth of 2.5 mm, then to 5 mm, 7.5 mm and so on, each time taking a photograph of the filled cast. Figure 2.13 shows a cast filled to a depth of 7.5 mm. When the series of photographs has been put on a computer, the images can be enlarged and the edges of the fluid traced precisely. The traced contours can then be superimposed on the palatograms.

The same lines, 5, 10 and 12.5 mm down from the highest point of the palate, can be easily drawn on the sagittal sections, as shown in figure 2.12. Using these lines and the contours it is possible to estimate the shapes of the tongue that occurred in each vowel. In the first palatogram, the marking medium has been wiped away above all three lines in the center of the mouth, indicating that the sides of the tongue must have gone within 5 mm of the roof of the mouth in this region. In the other two palatograms the contact area is further back. If

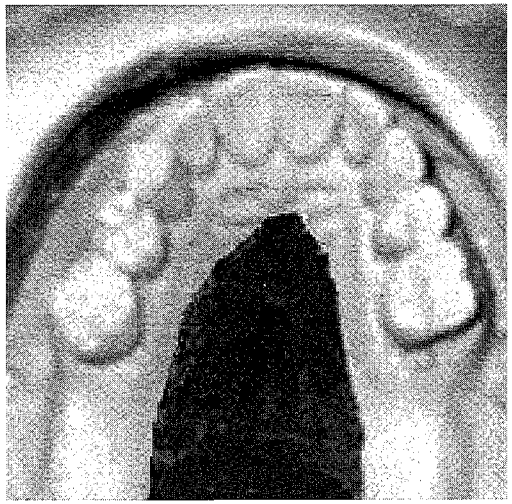

Figure 2.13 A cast of the roof of the mouth (filled to a depth of 7.5 mm).

we assume that the center of the tongue was slightly domed, making it a little higher than the sides, we can infer that the tongue shapes in these three vowels were approximately as shown in the sagittal sections in figure 2.12. The cast of the roof of the mouth did not extend as far back as the soft palate, so a dashed line has been drawn to indicate the sagittal section in that area.

Palatography is most helpful in studying consonants rather than vowels. A good example is provided by a set of data on Toda, a Dravidian language spoken in the Nilgiri Hills in India. Toda has four different sibilants exemplified by the words **koːs̻** 'money', **poːs̺** 'milk', **poːʃ** 'language', **poːs̢** (place name). (Toda is one of the comparatively few languages that has a larger number of contrasts at the ends of the syllables than at the beginning.) The palatograms of the words in figure 2.14 were made in the way described earlier in this chapter, first painting an oily black mixture on the tongue and photographing the black contact areas on the roof of the mouth, and then making another set of photographs, the linguograms, which were the result of painting the roof of the mouth and then photographing the black medium that had been transferred onto the tongue.

Two general points should be noted. Firstly, as we were interested only in articulations made in the front part of the mouth, we did not

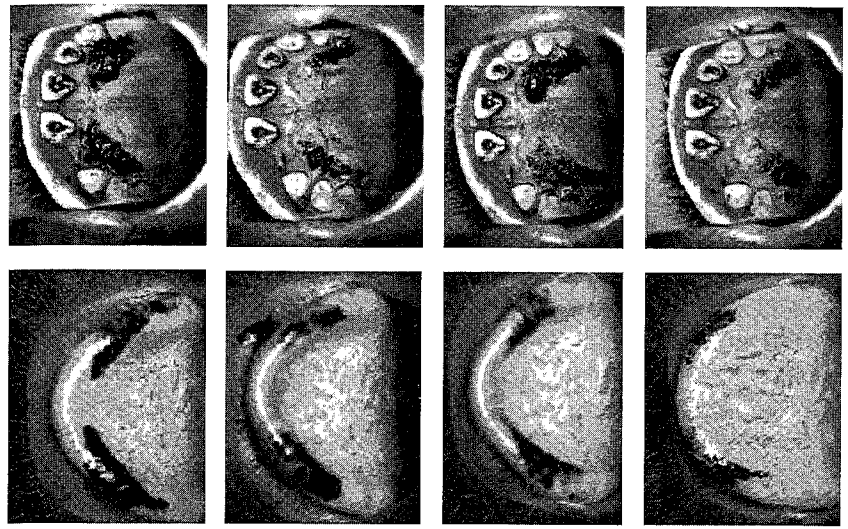

Figure 2.14 Palatograms and linguograms of four Toda words exemplifying the four voiceless fricatives in the language.

paint areas further back, nor did we try to photograph areas deep in the mouth. Speakers are always happier if they do not have to have their mouths wide open and a mirror placed deep inside. Secondly, all six of the Toda speakers we photographed had poor dentition, often missing several teeth. In addition, as they constantly chewed betel nuts, their teeth were very stained. The dark marks on the front teeth in all the photographs in figure 2.14 are stains, and not evidence of contact with the tongue. Photographs taken before making any palatograms can be useful in identifying permanent features such as these.

In the first word the tongue made contact with the roof of the mouth on the alveolar ridge, just behind the upper front teeth. There is no black on the tip of the tongue. When making these photographs we could see that the tip was down behind the lower front teeth in this word. We could also see that in the second word the tip was raised with, as the palatogram shows, the sides of the tongue making contact as far forward as the alveolar ridge. In the third word the contact was

The Toda are a small minority group, living in reserved areas in the Nilgiri Hills in India. They have some famous temples, but we were too busy to visit them. I'm not much of a tourist, and found it more fun to talk to our friendly Toda speakers, who entertained us well.

not quite so far forward. In addition, the distance between the black areas at the right of the photograph (between the molars) is smaller than in the second photograph. The body of the tongue must have been raised up towards the roof of the mouth in this word. The final word has a retroflex consonant. The contact on the roof of the mouth was very far back, and there is hardly any black to be seen in the photograph of the tongue. Most of the tongue contact involved the underside of the tongue, which is not visible in this photograph.

We made casts of all our speakers' mouths. From a study of the palatograms and linguograms and direct observations of the speaker, together with a knowledge of the contours of the speaker's mouth, it was possible to infer that the four shapes of the tongue involved in these four fricatives were as shown in figure 2.15. The results were

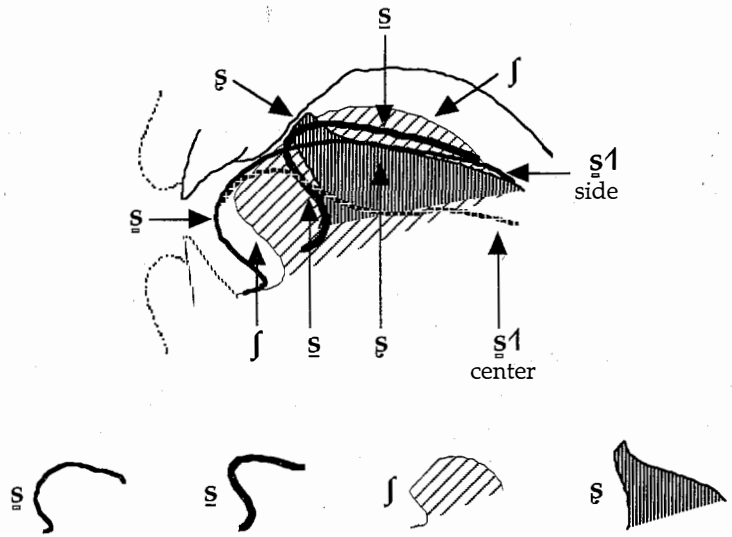

Figure 2.15 Inferred shapes of the tongue in the four Toda sibilants. For s̪ the solid line shows the sides of the tongue and the dashed line shows the center.

essentially the same for all six speakers. As I emphasized in the first chapter, it is always better to get data on a smaller set of words from many speakers than to conduct a massive study of a single speaker, who may or may not use articulations that are typical of the language.

2.4 Electropalatography

There are other systems of palatography. Dynamic electropalatography (EPG) is a valuable tool for showing changes in the contact areas on the roof of the mouth. This technique cannot be used in most field circumstances or for a one-time speaker in a lab, as it requires a special false palate to be made for each speaker. (Flexible palates that can be used by different speakers have been made, but are generally not very useful.) This palate has a number of contact points (96 in one system) that will record whenever they are touched by the tongue. It has to fit exactly into the speaker's palate and is fairly costly to make. Figure 2.16 shows the arrangement of the contact points and the wires connected to each of them, which eventually join together into two thicker wires that can come out at the sides of the mouth.

Dynamic EPG allows one to study movements and, given some additional programming, look at the palate from different angles. Pat

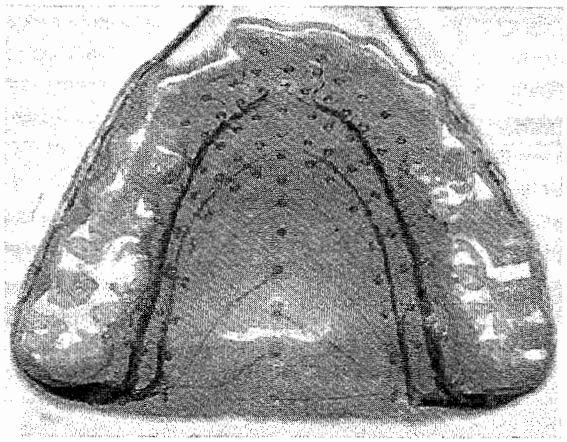

Figure 2.16 A false palate that fits inside a particular speaker's mouth. There are 96 electrodes connected by wires that join together into two thicker wires.