



# Google DeepMind

## Challenge Match

8-15 March 2016



## Game 4: "Endurance"

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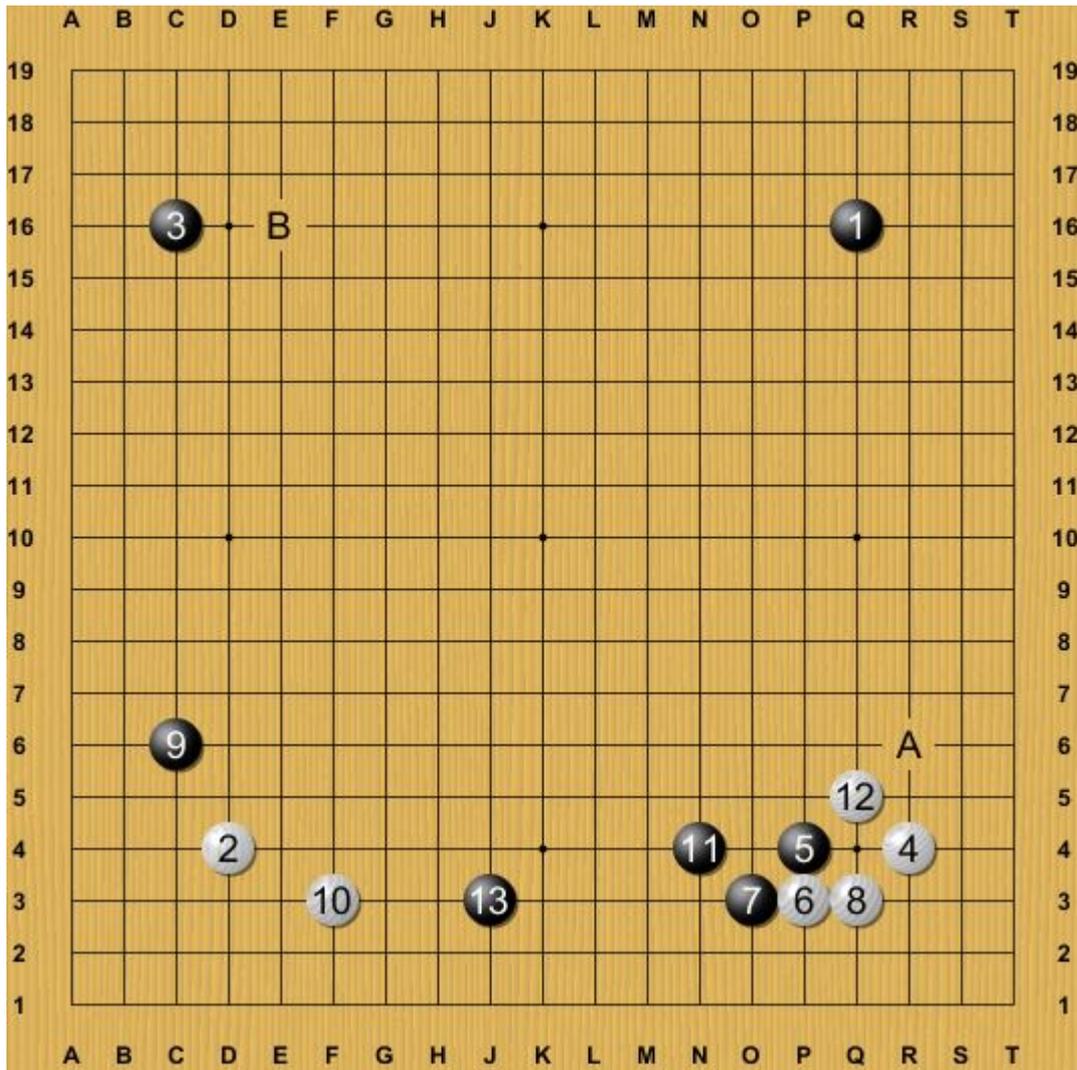
# Endurance

When I arrived in the playing room on the morning of the fourth game, everyone appeared more relaxed than before. Whatever happened today, the match had already been decided. Nonetheless, there were still two games to play, and a true professional like Lee must give his all each time he sits down at the board.

When Lee arrived in the playing room, he looked serene, the burden of expectation lifted. Perhaps he would finally recover his composure, forget his surroundings, and simply play his best Go. One thing was certain: it was not in Lee's nature to surrender.

There were many fewer reporters in the press room this time. It seemed the media thought the interesting part was finished, and the match was headed for a final score of 5-0. But in a game of Go, although the information is open for all to see, often the results defy our expectations. Until the final stone is played, anything is possible.

## Moves 1-13

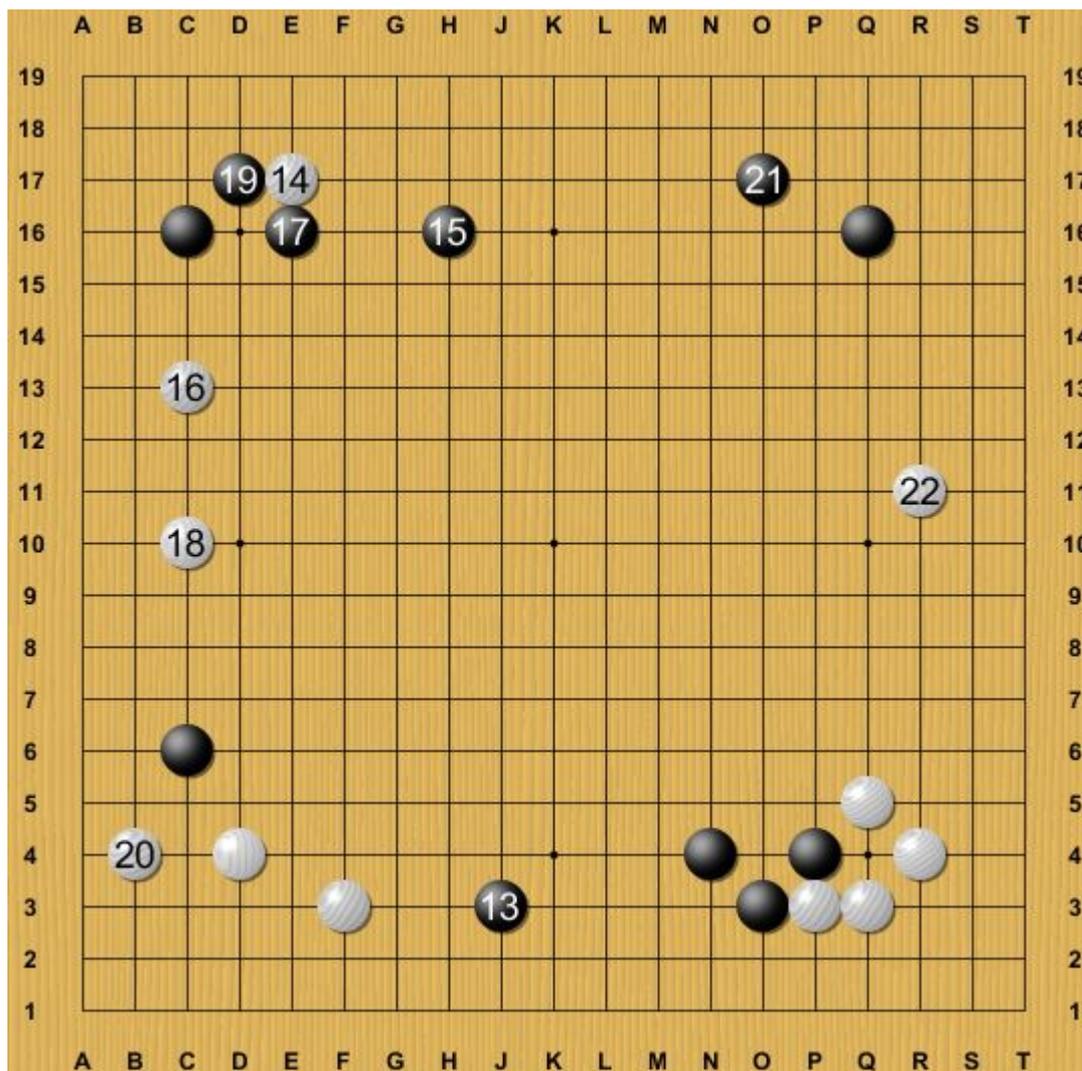


For the fourth game, Lee took White. Up to move 11, the opening was the same as the second game. AlphaGo is an extremely consistent player, and once it thinks a move is good, its opinion will not change.

During the commentary for that game, I mentioned that AlphaGo prefers to tenuki with 12 and approach at B. Previously, Lee chose to finish the joseki normally at A. White 12, however, is an interesting alternative! Perhaps it was a test: would AlphaGo still tenuki as in game 2?

This time, AlphaGo chose the ordinary extension at 13. After this move, AlphaGo's win rate was 50.5%. Both players had 1 hour and 52 minutes apiece.

## Moves 13-22

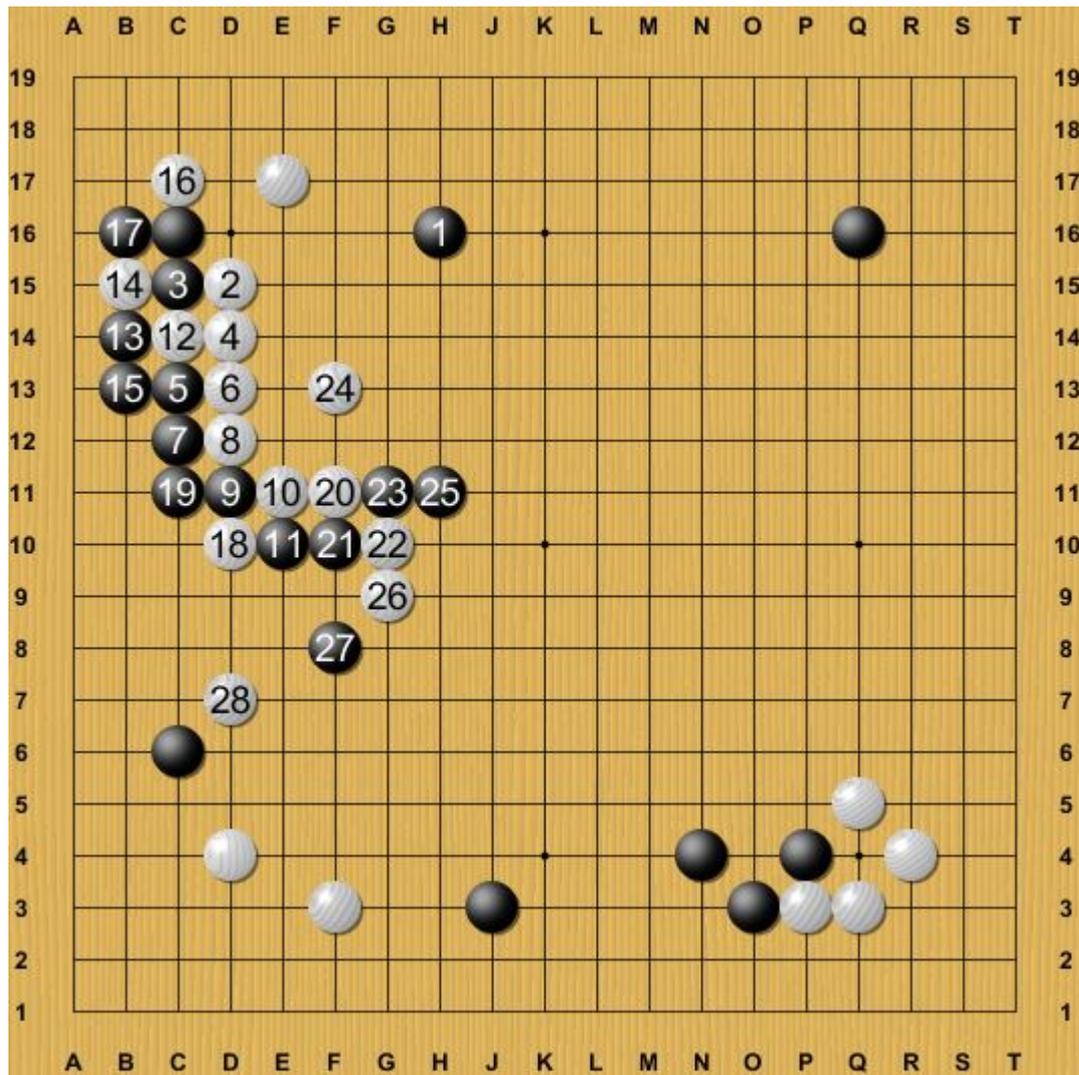


White played the usual corner approach at 14. Against Black's pincer at 15, Lee counter-pincer at 16 to emphasize the left side. However, AlphaGo preferred the press in diagram 1.

At move 21, Lee had 1 hour and 40 minutes left, AlphaGo 1 hour and 47 minutes.

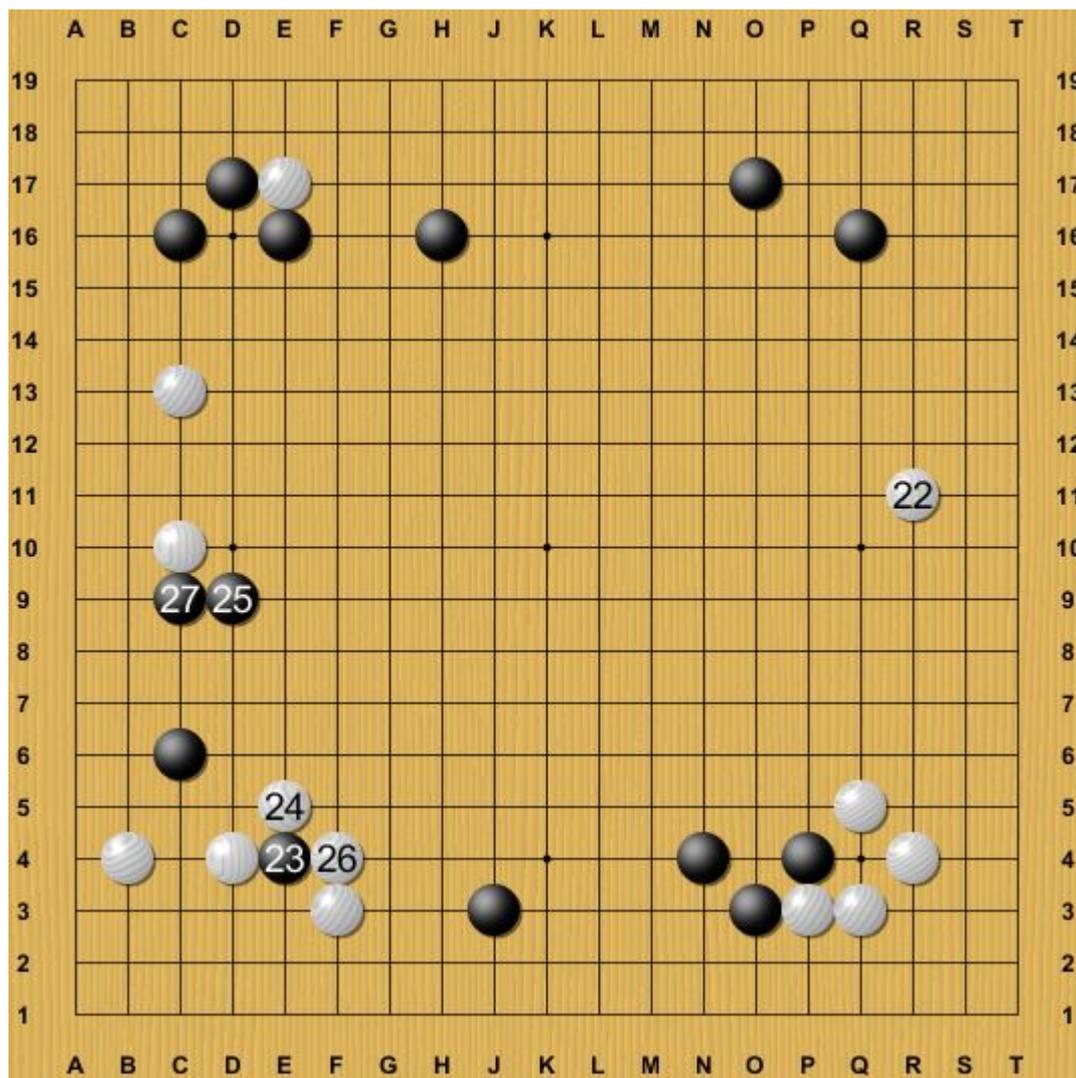
Up to 22, the opening was balanced, and AlphaGo's win rate stood at 53%.

Diagram 1



AlphaGo suggests pressing with the knight's move at 2, leading to a fight on the left side through 28. This by no means represents the best moves for both sides, but perhaps we can experiment with this strategy in future games.

## Moves 22-27



The better people got to know AlphaGo, the more started calling it by friendly nicknames, such as "Master A" in China and "Master AI" in Korea. Although such names mean little on their own, they represented a growing acceptance of AlphaGo as a partner and teacher, together with whom we could advance our understanding.

During this competition, "Master A" never ceased to surprise, playing at least one extraordinary new move in every game. Move 23 was the first such display in game 4.

Theoretically, 23 is quite vulgar, as it induces White to strengthen the corner. However, since White's lower side is already solid, if this move helps Black on the outside, is it really as crude as it looks? See diagram 2.

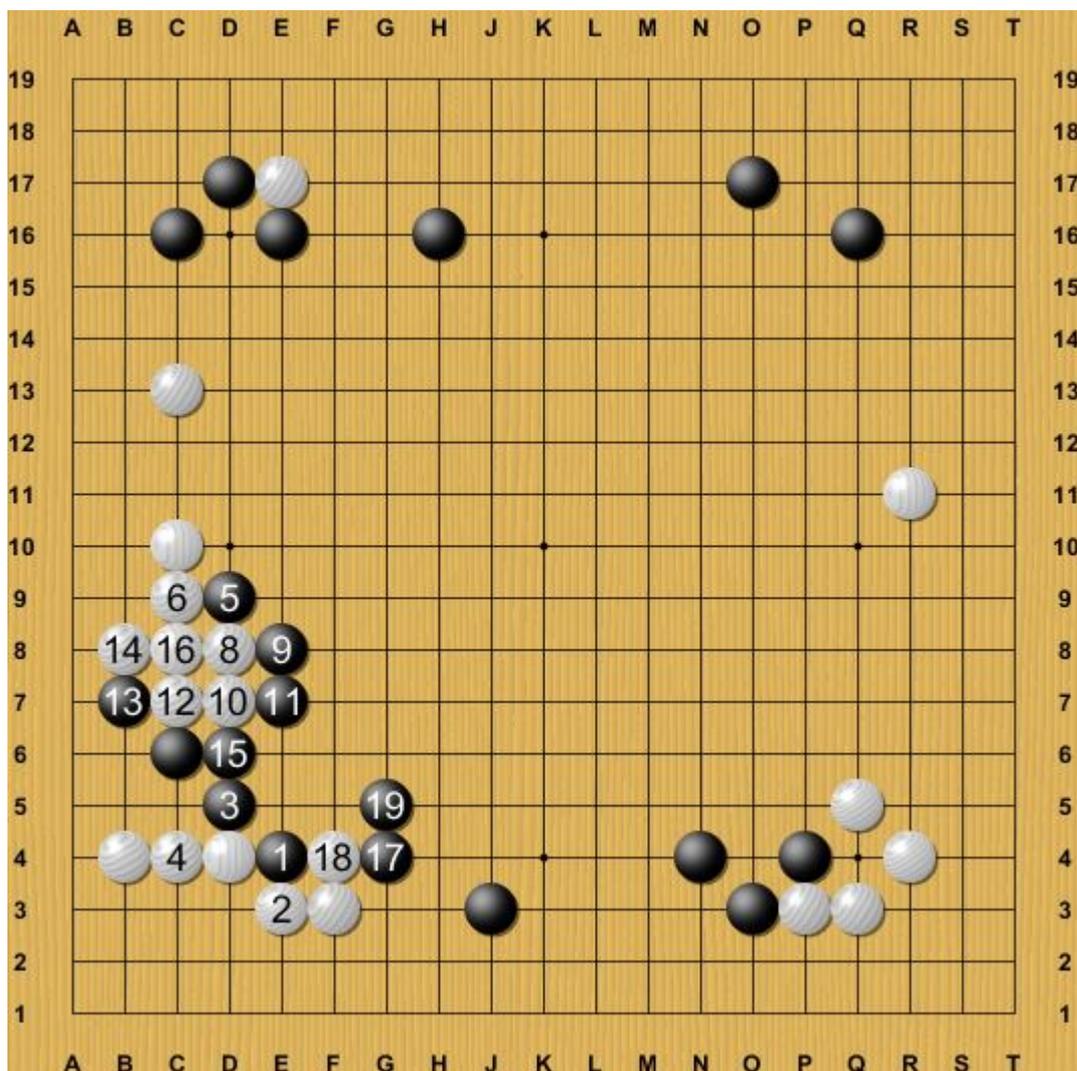
One of the major ideas in Chinese philosophy, from kung fu to Taoism, is the notion that "formlessness defeats form." This is not to suggest that one should do nothing, but rather that one should be ready to make use of any resource at any moment. In other words, complete flexibility is the surest path to success. When one is not committed to any style, there are no weak points at which to aim. Naturally, reaching this state demands a strong foundation and a formidable repertoire. AlphaGo seemed to have attained this "formless" style already: simple, easy to understand, and totally unexploitable.

Lee chose the outside hane at 24, and just as I was reading out the cut, AlphaGo changed course with the shoulder hit at 25. Lee cracked a smile, as if he were looking at a naughty child. AlphaGo was being mischievous indeed!

Coolly, Lee protected the corner with 26. Most players found this move too slow, and even AlphaGo thought White should respond with the crawl in diagram 3. Nonetheless, I saw this move as a sign that Lee had finally found the confidence to play his own game, regardless of anyone's approval. *This* was the Lee Sedol I knew: the wolf that, starving in the winter winds, still waited for his prey to come closer, biding his time for the moment his intuition knew would come.

When Black blocked with 27, AlphaGo's win rate was 55%.

Diagram 2

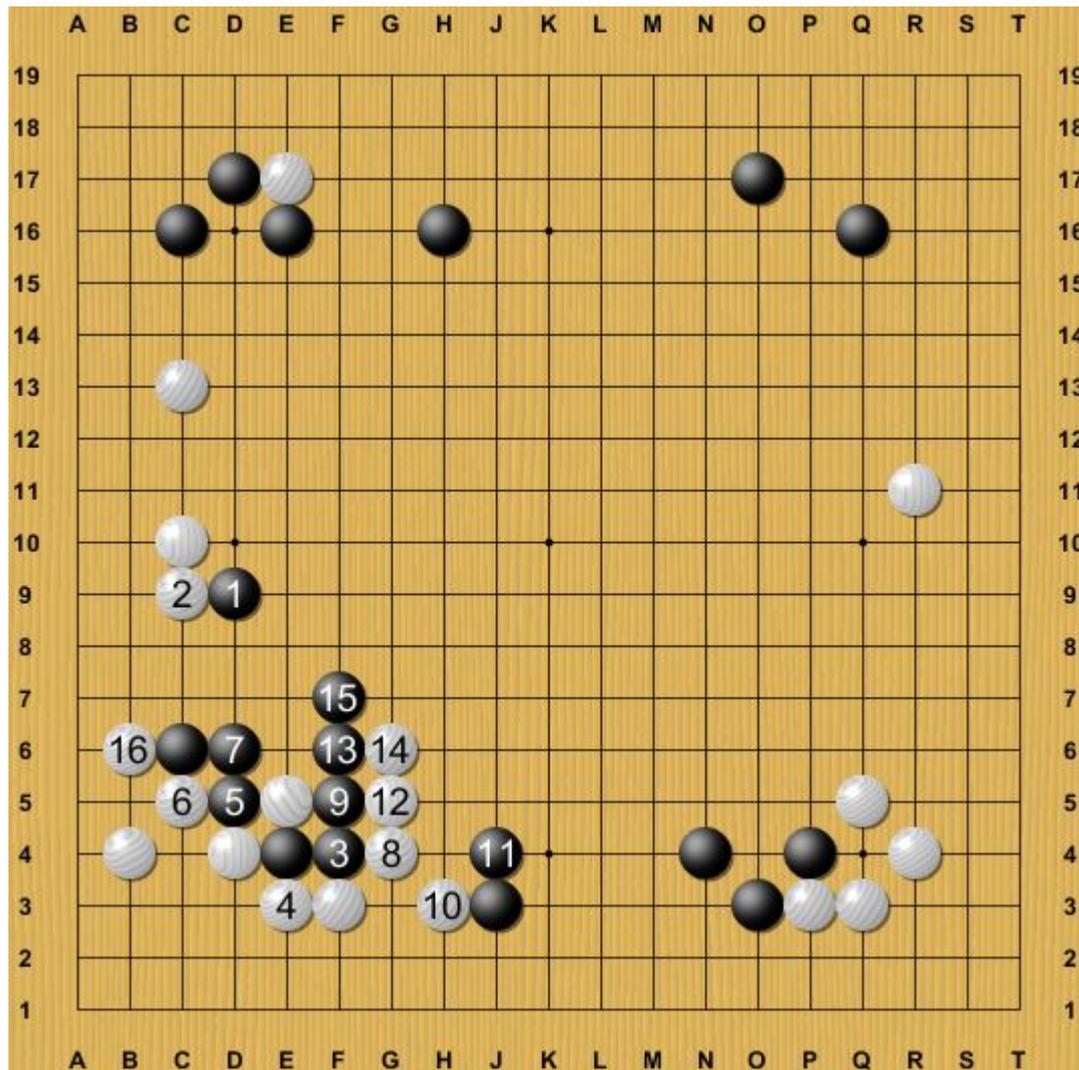


7=16

It is difficult to judge the pros and cons of exchanging 1 through 4, and professional commentators ventured a wide range of opinions.

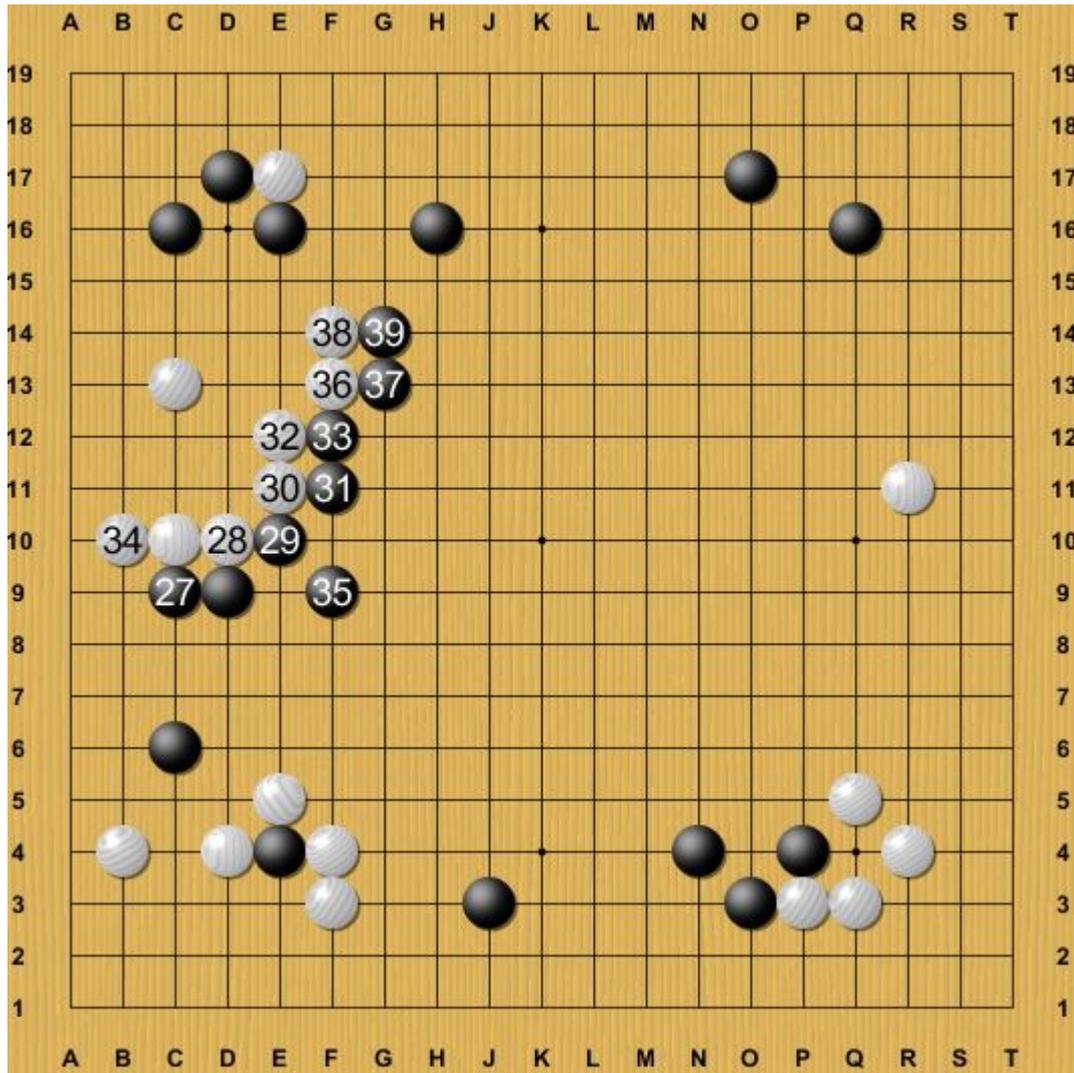
Following these preparations, AlphaGo was planning to play 5 and sacrifice a stone on the left to squeeze White, then enclose the corner with 17. This sequence looks interesting for Black.

Diagram 3



AlphaGo thinks White should crawl with 2, after which Black will set the stone at the bottom into motion with the sequence through 16. Zhou Ruiyang showed a similar variation in his own livestream.

## Moves 27-39



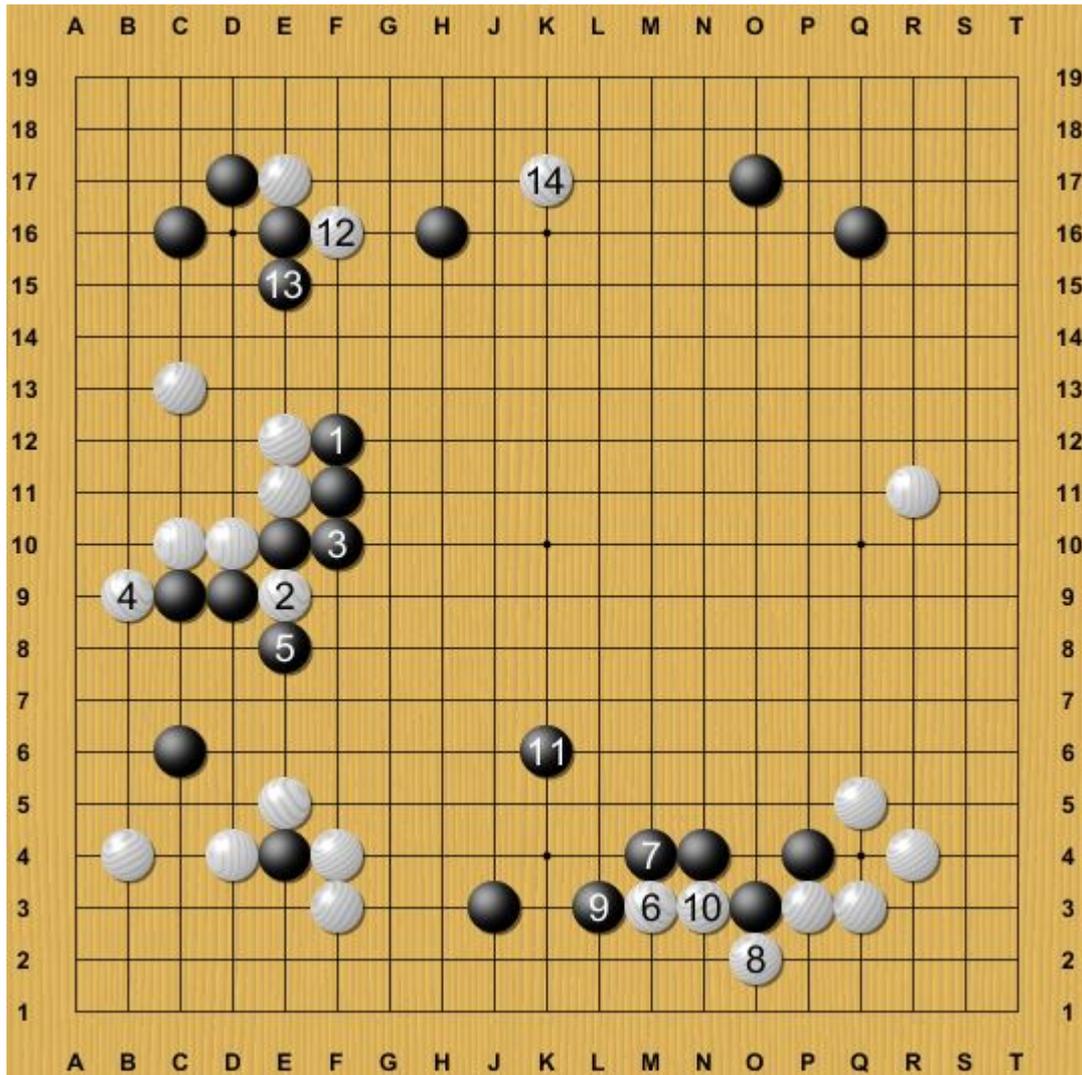
Perhaps because it was playing Black, AlphaGo played very aggressively during this game. With the double hane at 29 and 31, it seemed as if Black was attempting to completely overwhelm White. Even more shocking is that Lee submitted to it! Meek as a lamb, he let AlphaGo blockade the center and seal in White's group on the left side.

Sometimes to endure is difficult, sometimes it is irrational, and sometimes it is futile. Whatever it meant, Lee endured, and perhaps this was way of showing us his unwavering faith and unwillingness to surrender.

However, White did not need to suffer quite so badly. Diagram 4 offers one alternative.

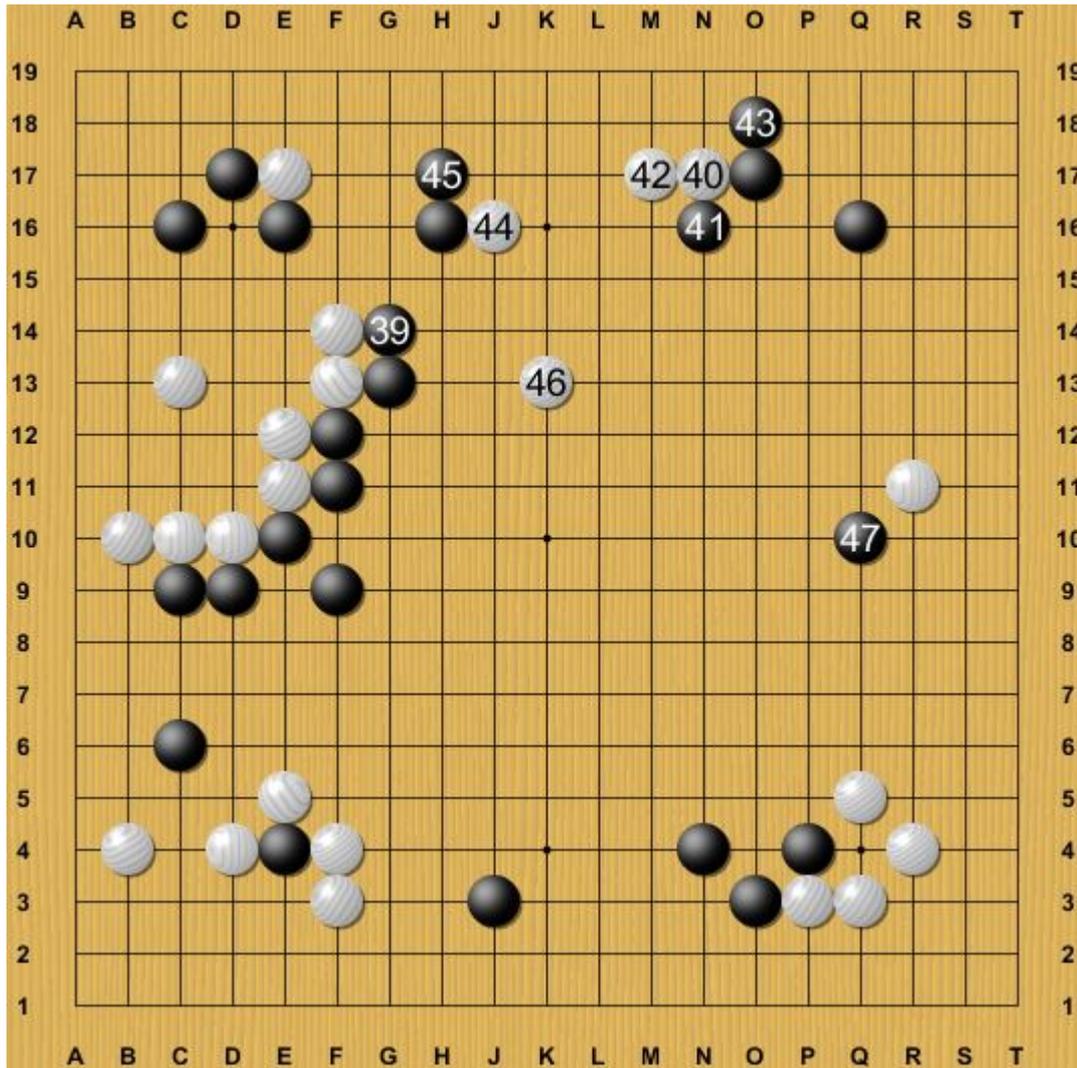
When Black played 39, AlphaGo's win rate reached 60%.

Diagram 4



When Black presses at 1, AlphaGo thinks White should atari at 2 and hane at 4. Black captures 2 in a ladder, but White can use the ladder breaker at 6 to invade the bottom. After 11, the bottom side is settled, and White can make use of the aji at the top to launch an invasion with 12 and 14. This way leads to a complicated battle.

## Moves 39-47



After Black had constructed such a thick wall, it became urgent for White to invade the top. The attachment at 40 was a classic technique to do just that.

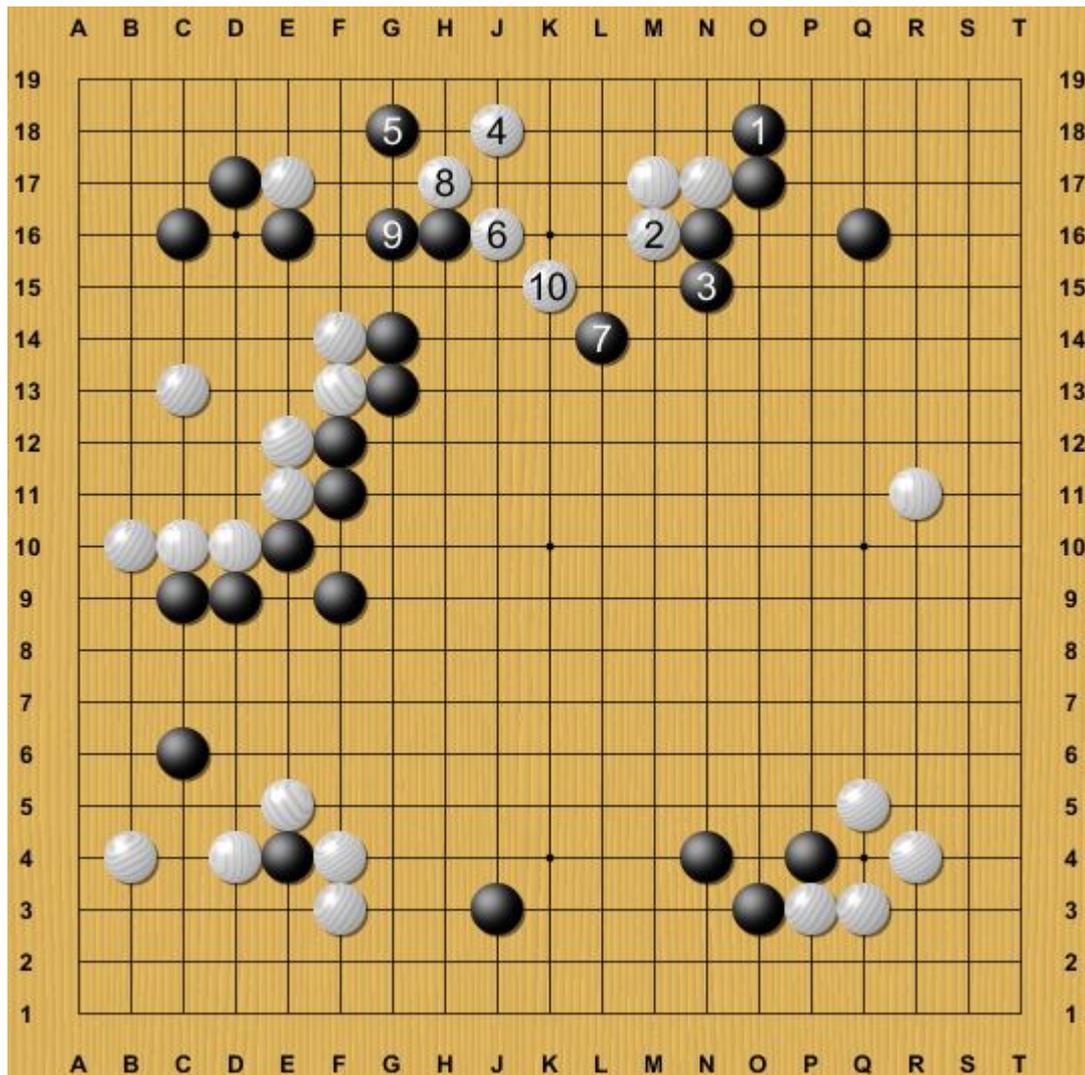
At move 41, Lee Sedol had 1 hour and 15 minutes left, AlphaGo 1 hour and 35 minutes.

AlphaGo thought move 44 was problematic. In view of Black's thickness, White's most attractive option would have been to live on the spot, as shown in diagram 5.

White gracefully leapt out into the center with 46, but Black 47 initiated a magnificent leaning attack!

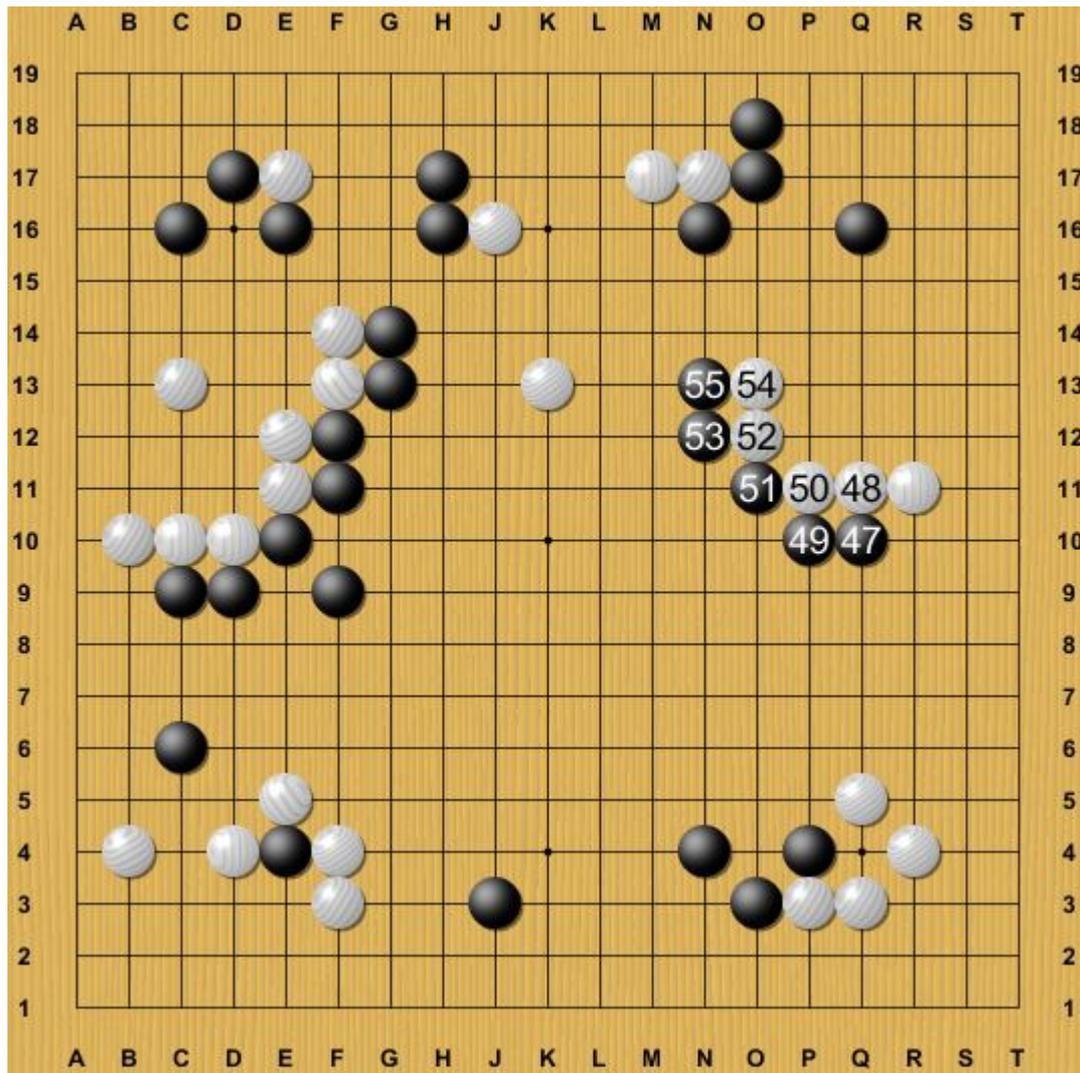
Compared to the previous games, Lee appeared much more relaxed and focused. Gone were the sighs, and the shaking of the head. Instead, he wore a look of intense concentration, as if waiting for something to arrive.

Diagram 5



AlphaGo thinks White should turn at 2, then create a base with the large knight's move at 4. Through 10, White makes life.

## Moves 47-55



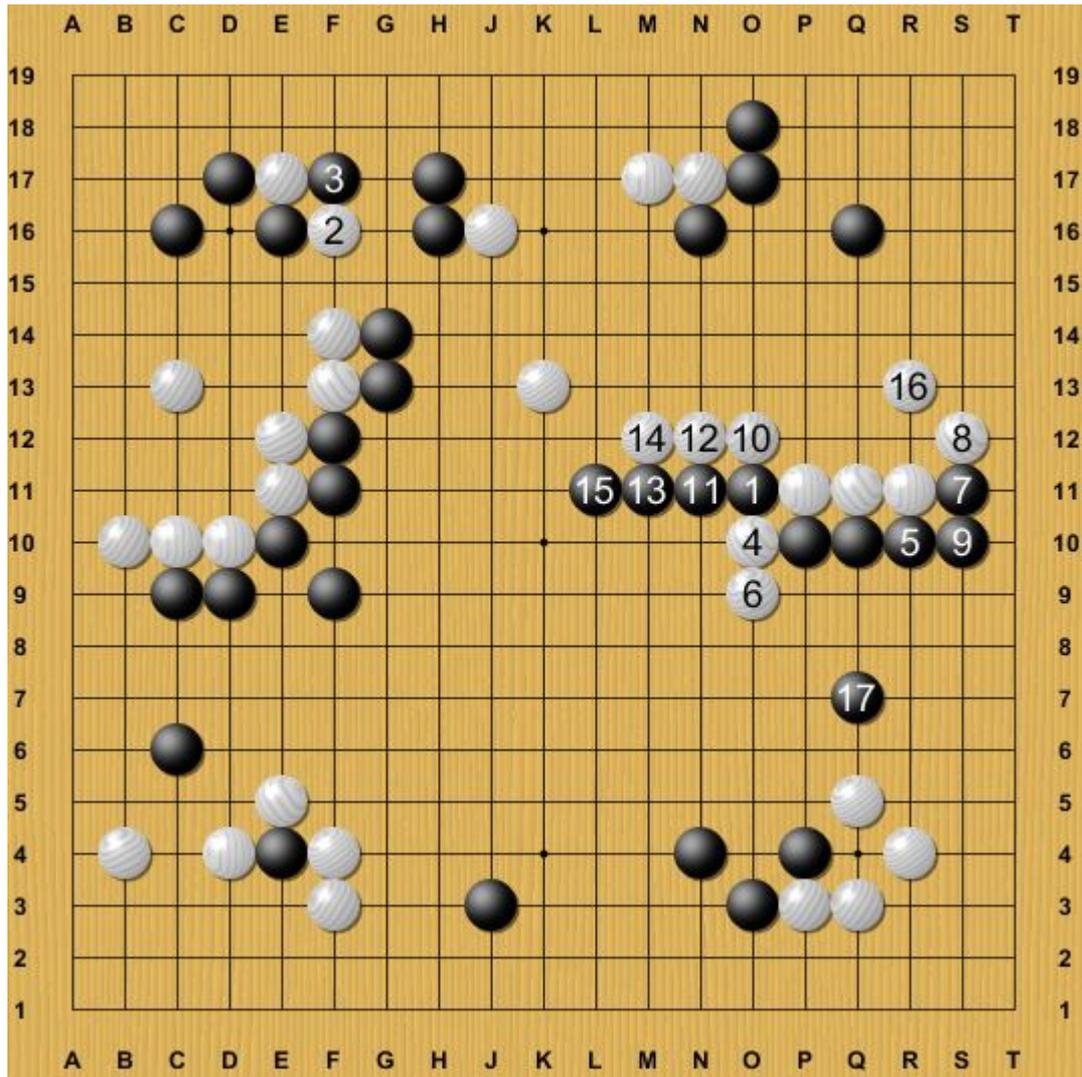
The greater the pressure became on White's top group, the more time Lee took to ponder each move. When Black played 51, Lee hesitated even longer. If Black dared to play so boldly, choosing the hane with only two stones to White's three, I could not imagine any move for White except the cut! Even AlphaGo thought cutting was the only move. See diagram 6.

But Lee continued to endure! Against Black's hane at 51, he hane at 52. Against the double hane at 53, he extended at 54!

"I can feel Lee's conviction," I wrote in my notebook, "waiting for the critical moment. But will that moment ever come?"

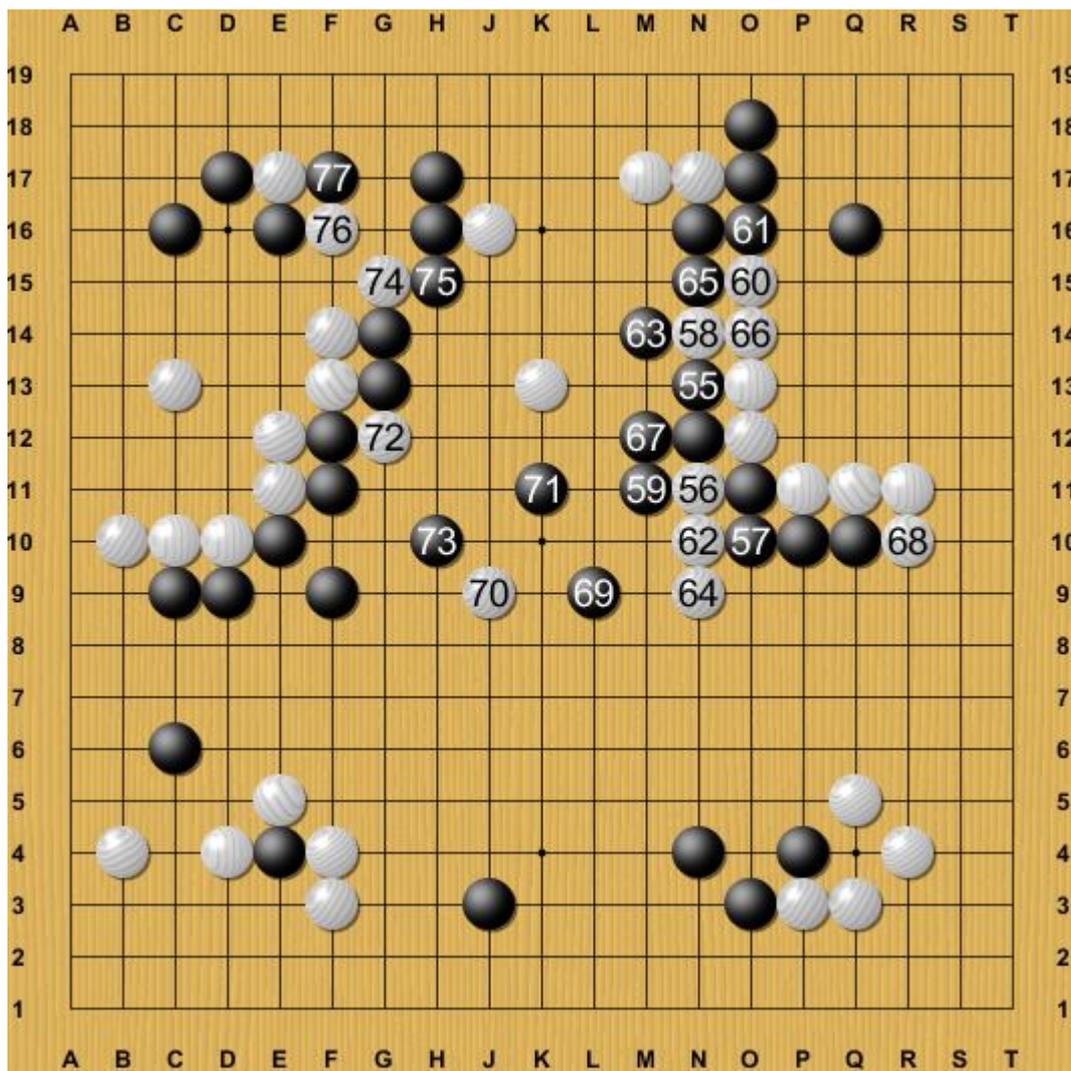
At move 54, Lee's clock had 51 minutes, AlphaGo's 1 hour and 28 minutes.

Diagram 6



AlphaGo thinks White should cut with 4. Through 17, the result is still a chaotic fight in the center.

## Moves 55-77



As the game progressed, it seemed to everyone that Lee was once again on the verge of defeat.

White played the atari at 56, followed by the hane at 58. When Black ataried at 59, White had the option of linking up the group on the top. See diagram 7.

Instead, however, Lee chose to pull out his center stone and extend at 62. With White's group now isolated and in grave peril, Lee's heart must have been overwhelmed with emotions. But perhaps he also sensed the long-awaited moment at hand.

At move 63, Lee Sedol had 42 minutes, AlphaGo 1 hour and 22 minutes.

At this point, people suddenly began to congregate near the playing room. The rumor was spreading that the game was about to end, with AlphaGo victorious as expected. But Lee looked cool-headed as ever as he played the turn at 68. Was he really not afraid of dying?

At move 69, Lee had 34 minutes, AlphaGo 1 hour and 19 minutes.

AlphaGo continued striding forward with the knight's move at 69, aiming to swallow the white group whole. Lee pondered deeply over his next move. If White was to have any chance, he would have to seize it now.

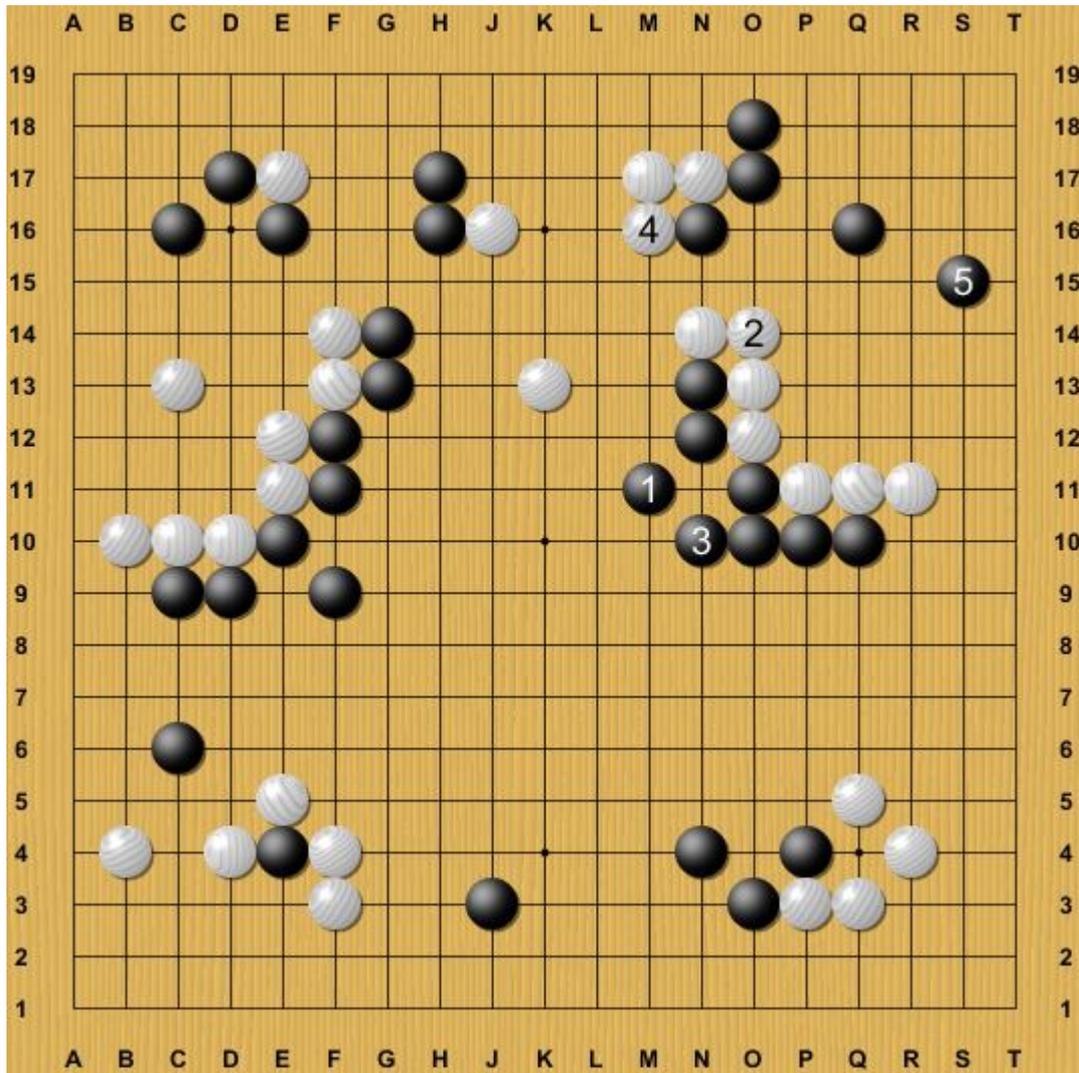
When Black closed off the center with 71, Lee had 27 minutes, AlphaGo 1 hour and 17 minutes.

After ten minutes of thought, Lee cut with 72. Right on schedule, one minute later, AlphaGo enclosed White's cutting stone with 73. Lee sighed, and kept thinking.

At move 77, Lee had only 11 minutes left. Moreover, AlphaGo's win rate had climbed over 70%. It seemed the game was over.

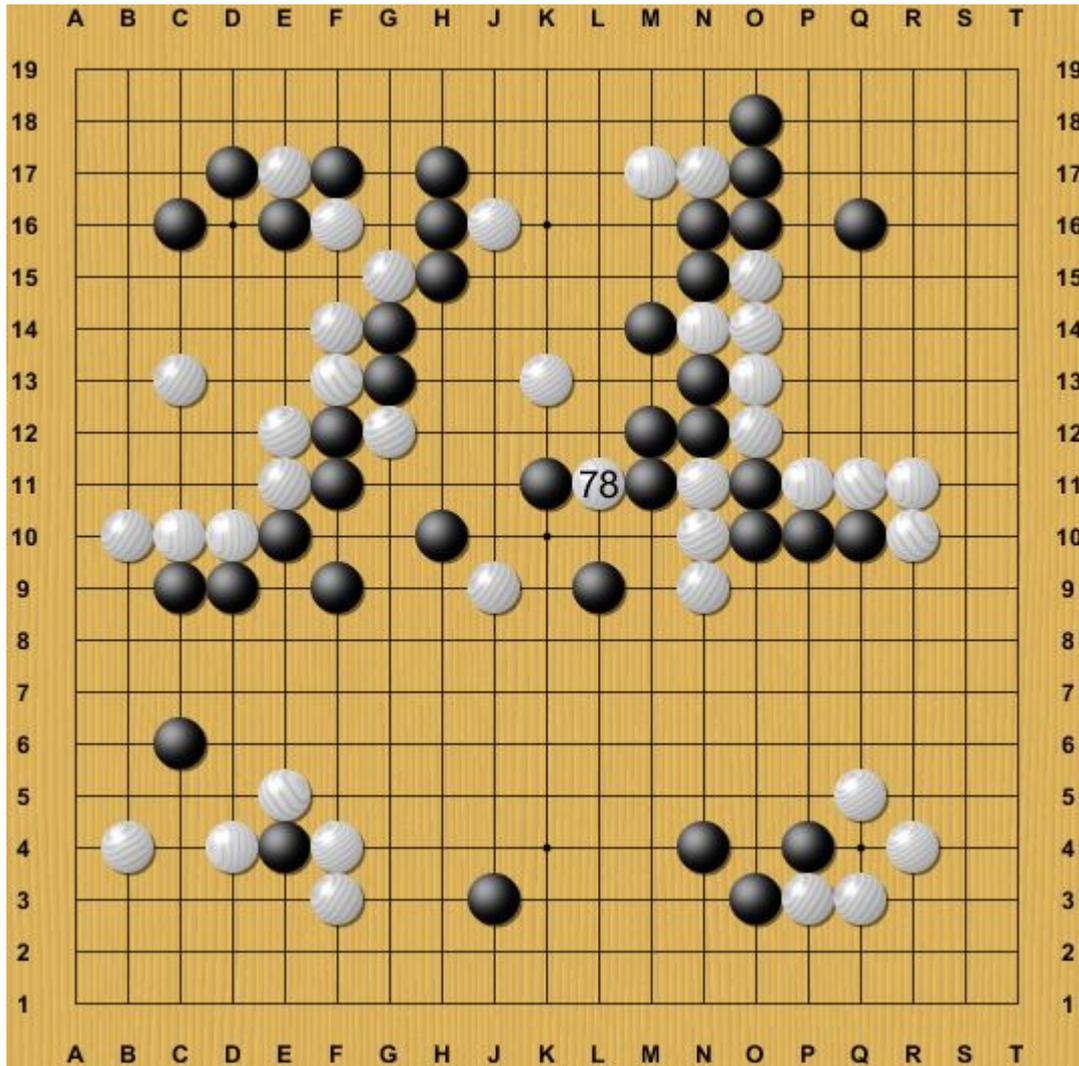
In fact, Lee had just completed the last of the preparations for his final charge!

Diagram 7



AlphaGo thinks White's best strategy is to connect with 2. Black would take the lone white stone in the center. After 4, White saves everything, but Black retains a clear lead by defending the corner with 5.

## Moves 78



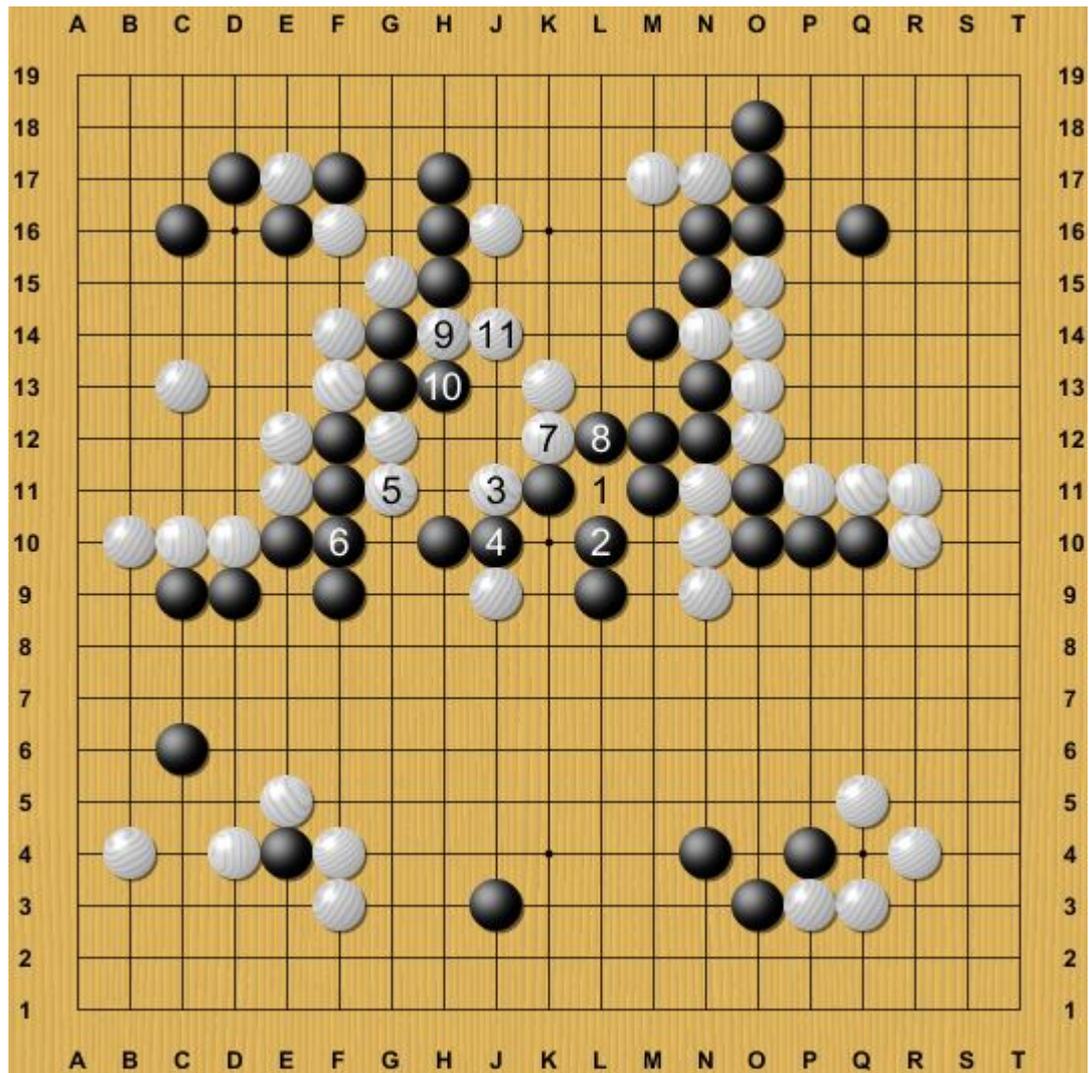
At last, Lee Sedol launched his attack. Like an earthquake, the wedge at 78 tore apart the cracks in Black's fortress! None of us had anticipated this. When Gu Li saw White 78 from his broadcasting studio in China, he shouted: "The divine move!" All of Lee's painstaking preparations were finally about to bear fruit.

Actually, Lee spent very little time on this move itself. Later, during the press conference, he told the assembled reporters that he had not spent much time calculating. He had simply played what felt right.

Without a doubt, this move is a spectacular flash of insight - but does it really work? See diagrams 8 and 9.

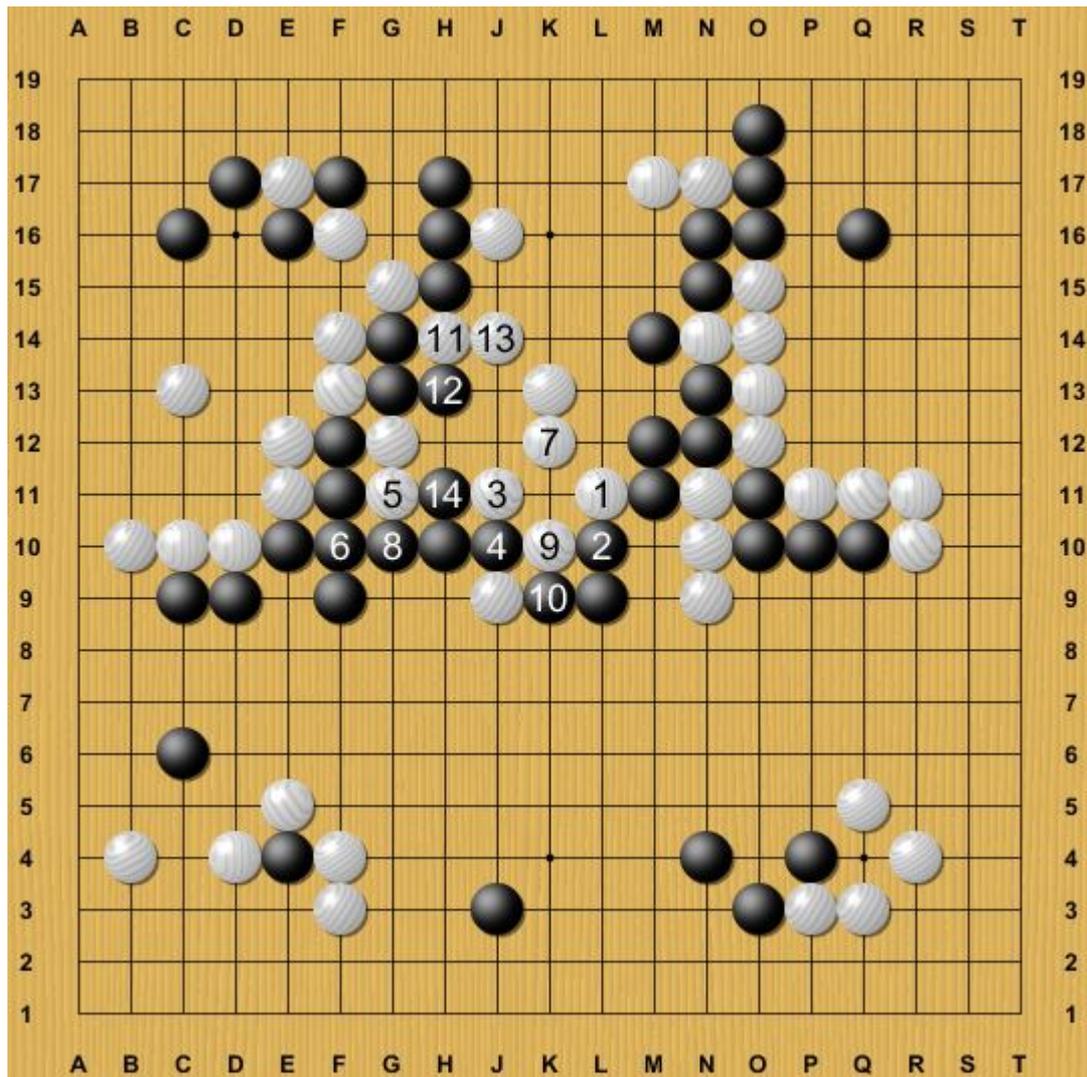
Regardless, this move cast AlphaGo into complete confusion.

Diagram 8



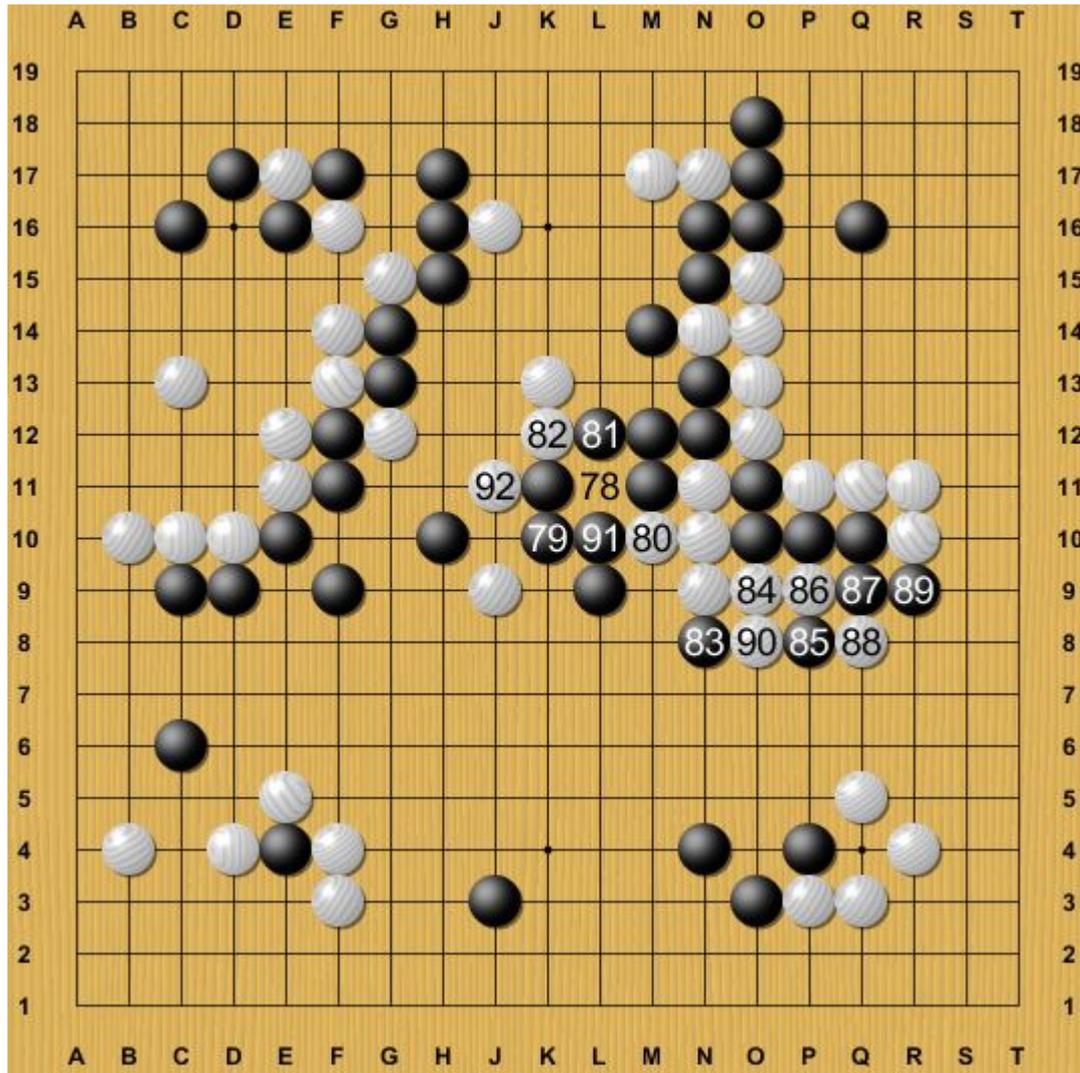
White's plan is simple: If Black answers at 2, White will use the aji of the surroundings to kill the three black stones. Through 11, the three stones are captured, White is connected, and Black is lost.

Diagram 9



However, professionals discovered that White 1 does not actually work! When White ataris with 7, Black need not capture, but can connect instead at 8. Due to the shortage of liberties, the sequence in the previous diagram fails. White is obliterated.

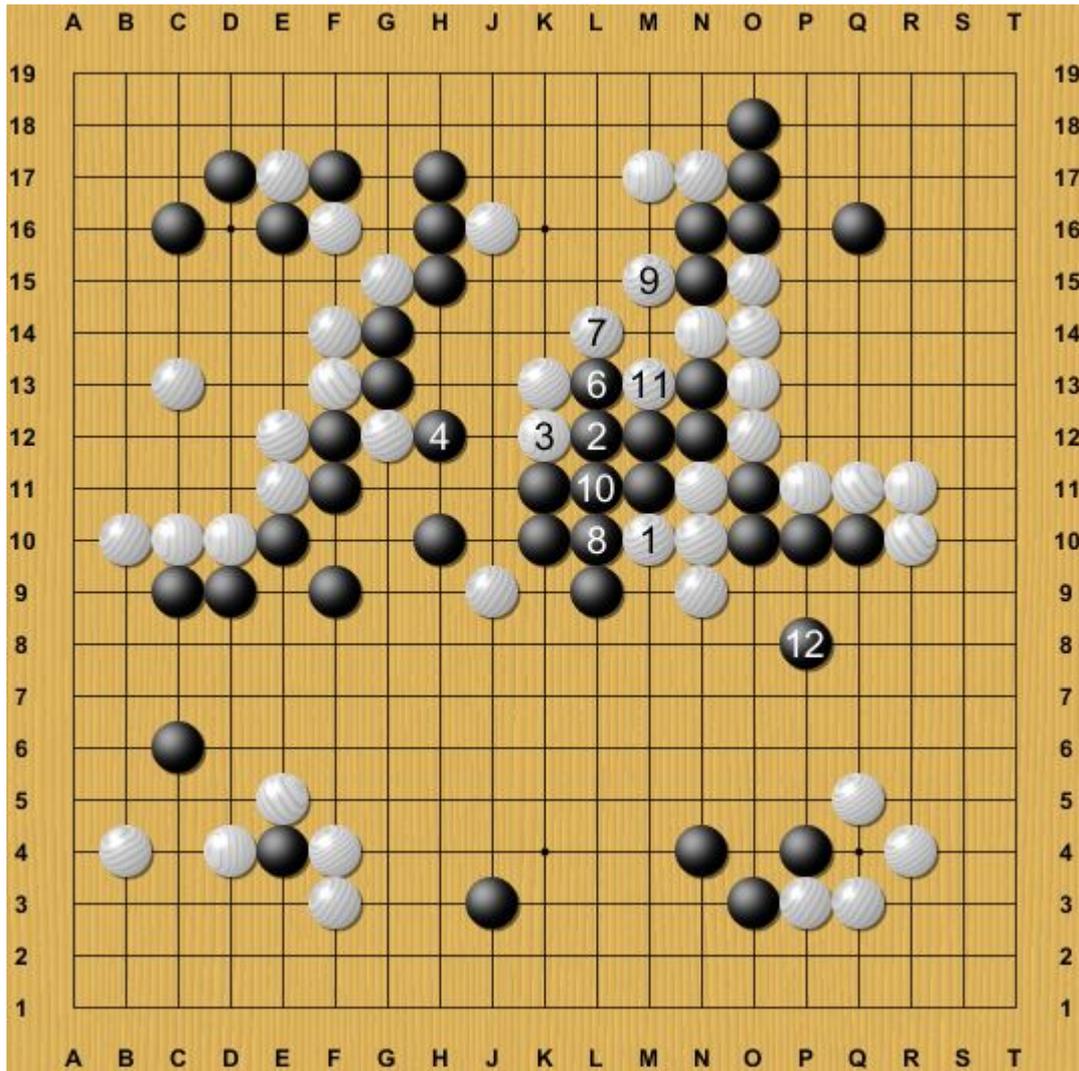
## Moves 78-92



Move 78 might not really work, but AlphaGo was at a complete loss to deal with it. When Black pulled back with 79, White blocked at 80, and Black could no longer kill the white stones unconditionally. Everybody thought AlphaGo was aiming for the ko in diagram 10, but suddenly it changed course. Inexplicably, it began trying to extract the dead stones on the right side! When White hane'd at 92, it was already difficult for Black to contain the white stones.

At this point, AlphaGo's win rate was in free fall. When White played 92, it dropped all the way to 55%, a full 15 points lower than before! What was going on?

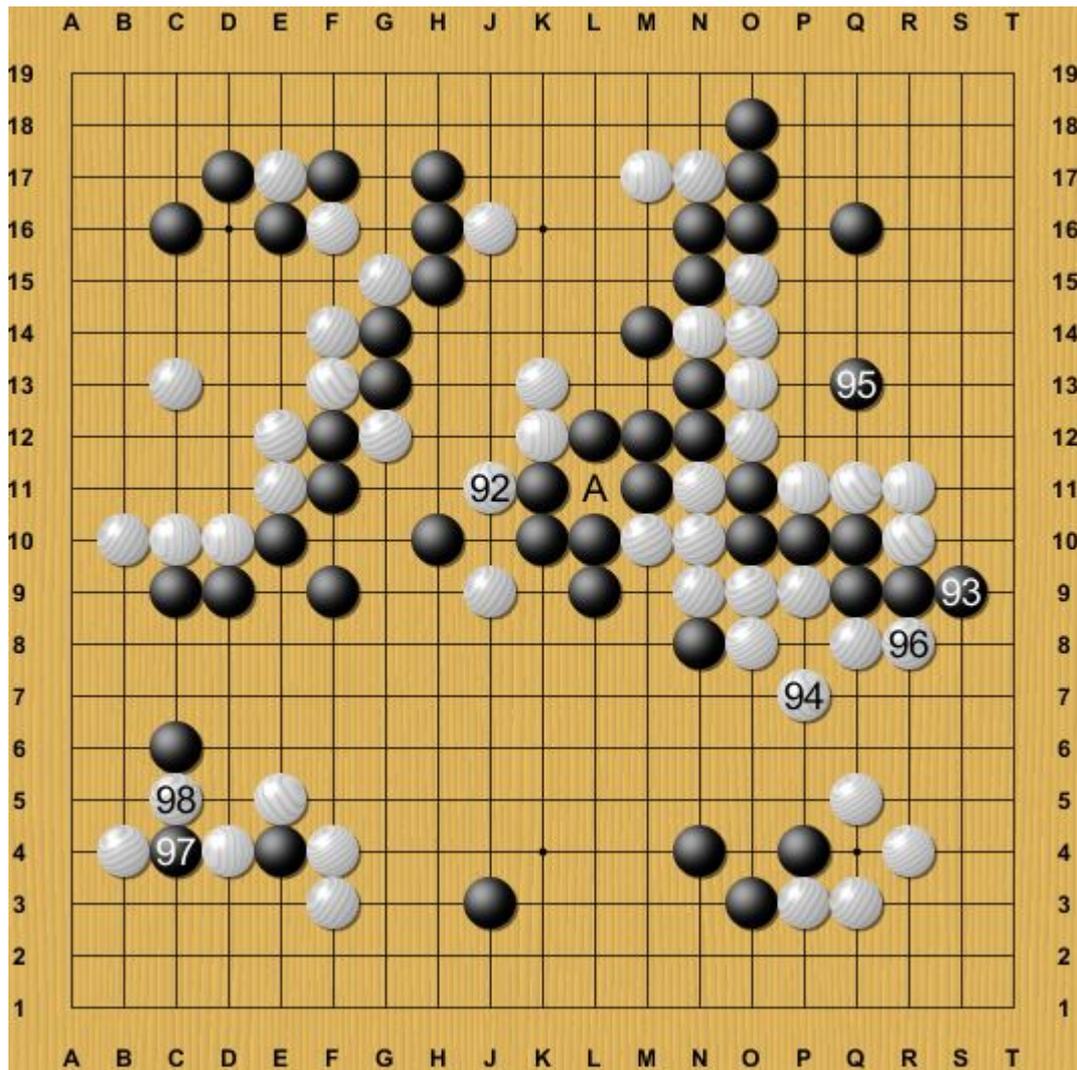
Diagram 10



5=11

Black should simply protect with 4. White can use the throw-in to connect in ko, but Black can save the four stones on the right with 12, and the game remains difficult for White.

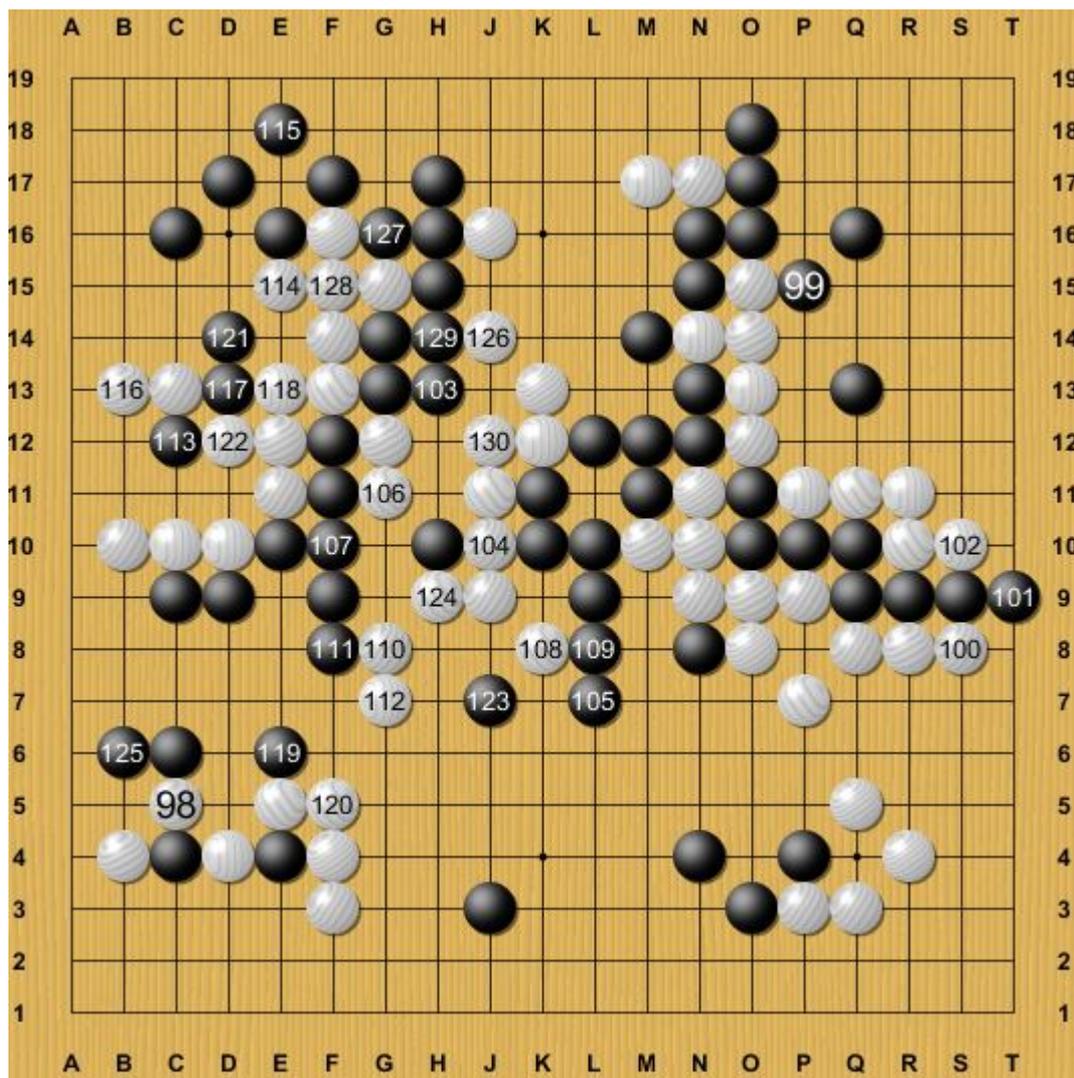
## Moves 92-98



AlphaGo seemed to have gone crazy, and began thrashing around wildly. The exchange of 93 for 94 reinforced White's center with no compensation. The wedge at 97 was completely beyond understanding! Aja Huang, who had been the picture of calmness since the beginning of the match, now looked at me as if to ask, "What's happening!?" I answered with a look that said, "I don't know."

Even now, we still do not know why AlphaGo lost its mind, playing senseless blunders one after another. Only one thing is certain: the original cause was the wedge at A, Lee Sedol's mystical "divine move." White 78 was incontrovertible proof of his determination to fight on, and his perseverance was rewarded with victory.

## Moves 98-130



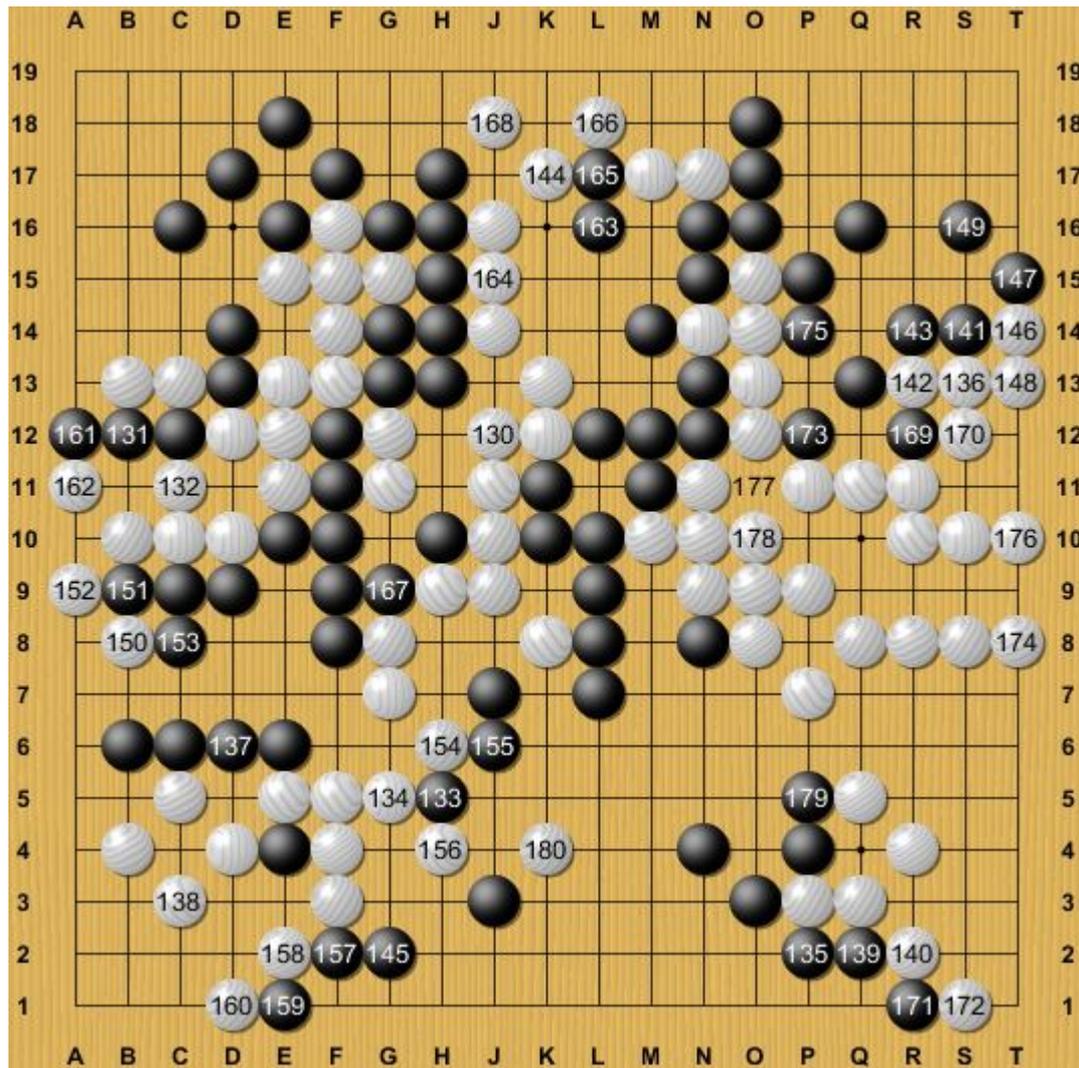
Little by little, AlphaGo recovered its sanity, but too late to save the game. When Black played 103, AlphaGo's win rate had fallen to 30%, the first time such low numbers had appeared since the match began.

At this point, Lee entered byo-yomi, but for the first time, he was seeing the light of victory.

The press room had been half-empty for some time, but now people began to pour in. Many reporters had already left, but when they heard that Lee Sedol might win, they turned around and came rushing back!

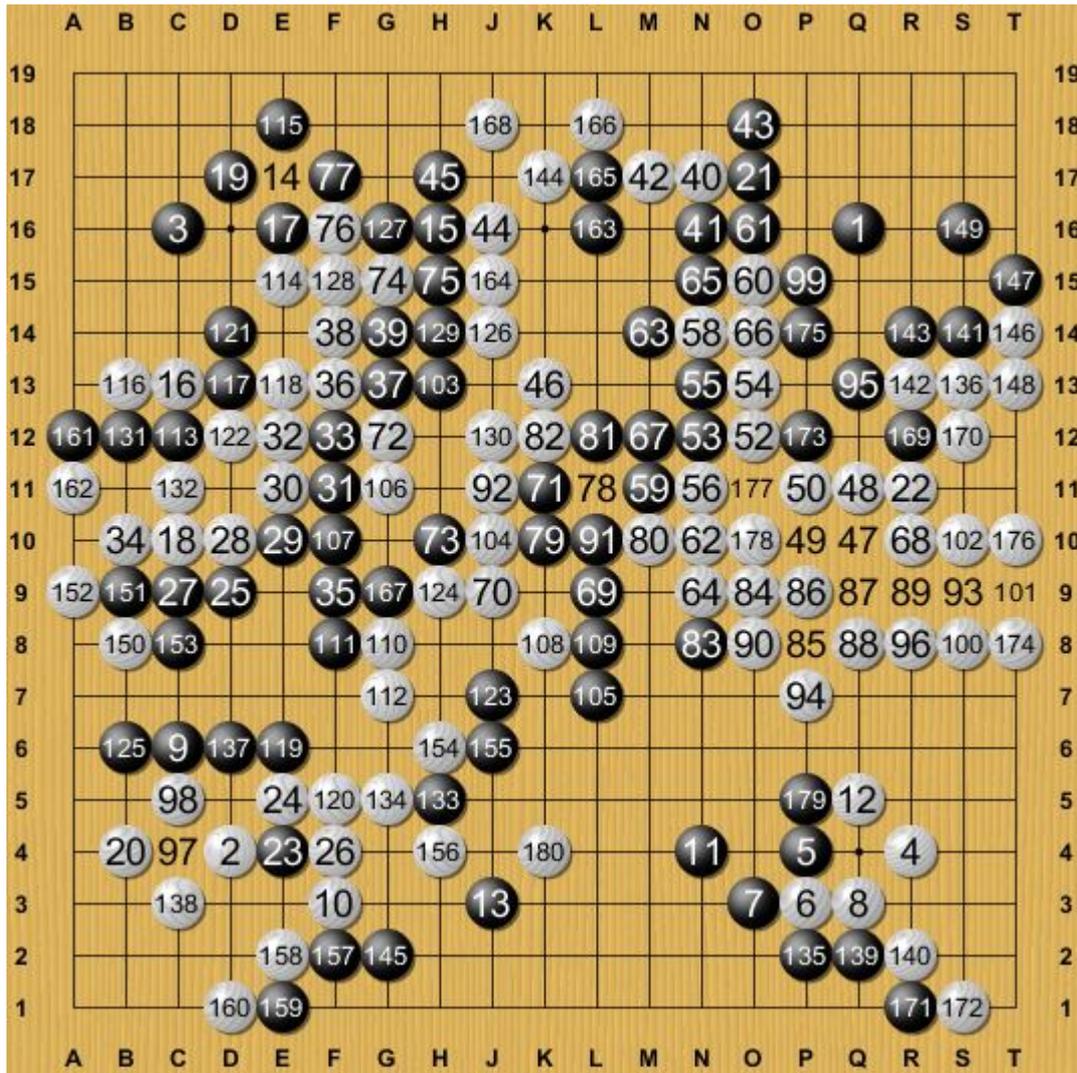
Everyone was anxiously awaiting the news of Lee's victory. As the professional commentators grew more and more certain of the conclusion, the game continued to progress onscreen. Playing in byo-yomi, Lee continued to answer AlphaGo's every move with utmost caution.

## Moves 130-180



At move 180, AlphaGo finally resigned.

## Full Game, 1-180



Lee Sedol entered the press room to thunderous applause. At long last, he could smile. It was a simple, modest smile, nothing world-changing - but then, aren't little moments like this the real source of joy in life?

